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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF ENTOMOLOGY—BULLETIN No. 59.

L. O. HOWARD, Entomologist and Chief of Bureau.

PROLIFERATION

AS A FACTOR IN THE NATURAL CONTROL

OF THE

MEXICAN COTTON BOLL WEEVIL.

BY

W. E. HINDS, Ph. D.,

In Charge of Cotton Boll Weevil Laboratory.

ISSUED AUGUST 27, 1906.

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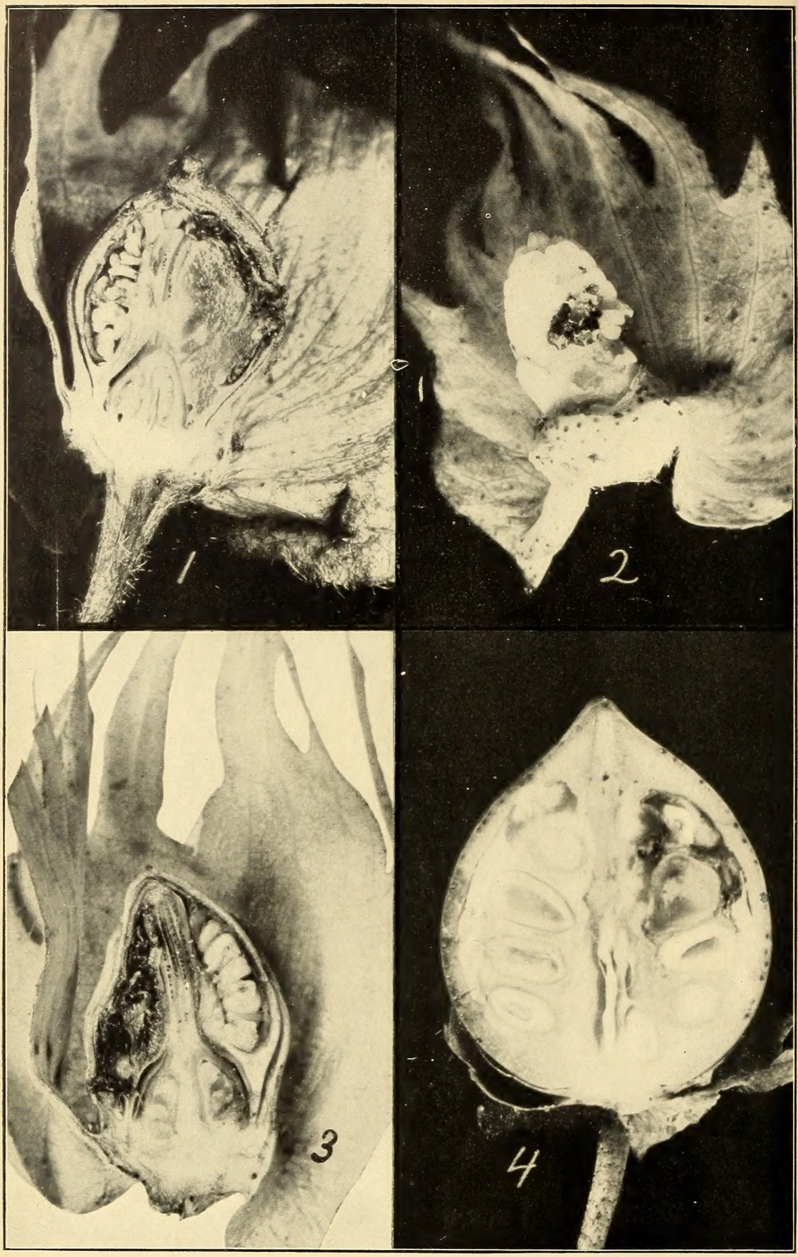

PROLIFERATION FROM WEEVIL FEEDING-PUNCTURES.

Fig. 1.—Right half of square filled with granular-appearing proliferation, enlarged four diameters. Fig. 2.—Interior of square, proliferation from feeding puncture, dried and brown, enlarged two diameters. Fig. 3.—Section through feeding puncture from which proliferation spread to tip of square, enlarged four diameters. Fig. 4.—Proliferation starting from feeding punctures in bolls, enlarged two diameters. (Original.)

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., April 10, 1906.

Sir: I have the honor to transmit herewith a manuscript prepared by Dr. W. E. Hinds, special field agent of this Bureau, engaged in work on the boll weevil. This manuscript is a study of the proliferation in the squares and bolls of cotton by means of which a certain percentage of weevil larvæ are killed. It does not deal at length with the botanical aspects of the question, but is rather a practical statement of the effect of this formation of loose tissue cells upon the boll weevil, based upon a large number of observations made by agents of the Bureau of Entomology. The botanical side of this phenomenon has been fully considered by Mr. O. F. Cook, of the Bureau of Plant Industry, and this paper is therefore supplemental to papers published by Mr. Cook on this subject. The preface is written by Mr. Hunter, and the conclusions in the paper have been revised by him. In addition to the general interest in the subject, the information given will be undoubtedly of distinct advantage to those engaged in cotton-breeding work, and I therefore recommend that it be issued as Bulletin No. 59 of this Bureau.

Respectfully,

C. L. Marlatt,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE

Aside from the habit of determinate growth, perhaps the most important tendency of the cotton plant that has the effect of avoiding damage by the boll weevil is that of proliferation in the squares and bolls, which was first observed by Dr. W. E. Hinds in 1902 at Victoria, Tex. The present paper places on record a large number of observations and experiments relating to this phenomenon, which have been carried on for several years by the boll-weevil investigation in Texas. The studies upon which the paper is based were planned primarily to determine the ways by which proliferation actually affects the weevil. Other features of proliferation have been dealt with fully by Mr. O. F. Cook, whose publications are referred to more specifically in the text. In addition to the general interest of the information given, much of it will undoubtedly be of special advantage to those who are engaged in cotton-breeding work.

As will be seen in the following pages, it has been ascertained that the rate of mortality among weevils in squares of American upland varieties of cotton is higher by about 13.5 per cent as a result of proliferation. This in itself is of no little significance, but it is to be noted that the greatest importance of proliferation is in connection with some of the foreign varieties of cotton, which seem to have this property developed to a much greater extent than the American upland varieties. Consequently, the discoveries of Mr. O. F. Cook, relating to the Kekchi cotton of Guatemala and the possibility of utilizing this cotton in the United States, are of great interest.

An important difficulty which will be encountered in the work of breeding cottons which proliferate to a great extent, will be the capability for adaptation on the part of the boll weevil. That this insect has considerable capability for adaptation is shown in the great variation in the size of the adults, the result of conditions of food supply in the immature stages to which it has adapted itself, as well as in many other ways. As a matter of fact, the capacity of the weevil for adaptation is probably fully as great as is the natural adaptive capacity of the cotton plant. Nevertheless, the interference of man may throw the advantage greatly in favor of the plant.

The work upon which this publication is based was performed under the general direction of the writer by Dr. W. E. Hinds. He was assisted in various ways by practically all the agents of the boll-weevil investigations, but more particularly by Messrs. A. C. Morgan, W. W. Yothers, W. Dwight Pierce, A. W. Morrill, and F. C. Pratt.

W. D. HUNTER,
In Charge of Cotton Boll Weevil Investigations.

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PROLIFERATION AS A FACTOR IN THE NATURAL CONTROL OF THE MEXICAN COTTON BOLL WEEVIL.

INTRODUCTION.

EARLIEST OBSERVATIONS.

Soon after the beginning of the laboratory work upon the cotton boll weevil at Victoria, Tex., in 1902, it was noticed that the attack of the weevil was frequently followed by a very decided change in the structure of the tissues near the point of attack in both buds and bolls. The significance of this change was not at that time fully appreciated, and the observations made upon the weevil did not include records as to the occurrence and effect of this phenomenon. For this reason the early observations made before the autumn of 1903 have furnished comparatively little material which could be used in making tabular statements, such as have been made from more recent studies of the effect of proliferation upon the development of the boll weevil.

When and by whom proliferation was first observed in cotton is not known to the writer, but no publication relating to this phenomenon prior to that made in Bulletin No. 45 of the Bureau of Entomology, pages 96 and 97, has been found. The earliest notes upon the occurrence of proliferation and its effect upon the weevil were made by the writer in September, 1902. Since that time there has been gradually accumulating in the notes of the agents of the Bureau of Entomology who have been studying the boll weevil, a large amount of data bearing upon this subject.

In the plans made for the work of 1904, at the beginning of the season, definite provision was made for observations upon this phenomenon in a number of varieties of cotton and for testing the influence of fertilizers in stimulating a greater manifestation of proliferation in the plants treated. Since that time the observations upon proliferation and its effect upon weevil development and injury have been carried on continuously.

SCOPE OF PRESENT DISCUSSION.

The present paper does not pretend to be a study of proliferation in the botanical aspects of the question, but rather a practical statement of the large number of observations made by agents of the Bureau of Entomology primarily regarding the effect of this formation of loose tissue cells upon the boll weevil. It is consequently of an entomological and not a botanical character. The botanical significance of the phenomenon has been very fully considered by Mr. O. F. Cook, of the Bureau of Plant Industry, to whose publications among those listed below[a] the reader is referred for a discussion of that part of the subject.

DEFINITIONS.

In order that the statements here made may be readily understood by one who is not familiar with terms used in botany or entomology a few general definitions may be in order. In Bulletin No. 45 of the Bureau of Entomology, concerning the cotton boll weevil, the term "gelatinization" was used instead of proliferation, as it was believed that its significance would be better understood by the average reader, though it was realized that, strictly speaking, the term used expressed an incorrect idea concerning the nature of the change to which it referred. The term "proliferation" is in general use both in botany and zoology, to denote a growth by the multiplication of elementary parts. In the present case we may define proliferation as being the development of numerous elementary cells from parts of the bud or boll which are themselves normally the ultimate product of combinations of much more highly specialized cells. The resulting product is thus composed of comparatively large, thin-walled cells, which are placed so loosely together that the resulting formation is of a soft texture, and has a granular appearance (Pl I, fig. 1) which may be plainly seen with the unaided eye. The soft, pulpy nature of this growth led to the choice of the term "gelatinization" as being most appropriate to signify in a general way its appearance and texture. It appears that this formation may originate from various causes in almost any part of the bud or boll (Pl. I, figs. 2–4). Whatever may have been the inciting cause, the character of the formation appears very much the same in any case. Undoubtedly, however, certain tissues proliferate more readily than do others. In squares, the outer layer of the column upon which the stamens are borne appears to be especially susceptible to stimuli which produce this reaction. In bolls, the cells immediately adjoining the thin, hard layer lining the hulls or carpels are most frequently the point at which proliferation begins. In most cases the proliferation appears to begin very near to the point of injury, but from that point it may spread through an entire lock, or to all the inner parts of an injured bud.

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[a] Bibliography of Proliferation:

1904. Hunter, W. D., and Hinds, W. E.—The Mexican Cotton Boll Weevil. Bul. No. 45, Bureau of Entomology, U. S. Dept. Agric., pp. 96–97.

1904. Cook, O. F.—Evolution of Weevil Resistance in Cotton. Science, Vol. XX, pp. 666–670.

1905. Hunter, W. D., and Hinds, W. E.—Bul. No. 51, Bureau of Entomology, U. S. Dept. Agric., pp. 133–134.

1905. Cook, O. F.—Cotton Culture in Guatemala. Yearbook U. S. Dept. Agric., f. 1904, pp. 475–488.

1906. Cook, O. F.—Weevil Resisting Adaptations of the Cotton Plant. Bul. No. 88, Bureau of Plant Industry, U. S. Dept. Agric.

METHOD OF STUDY.

As the significance of these observations came to be more fully appreciated it was believed that they contained at least a suggestion as to some very promising lines of work in the problem of controlling the weevil. Accordingly, it has been necessary to study carefully the nature of the phenomenon, conditions of climate, soil, fertilizer, and variety of cotton which affected the occurrence of proliferation. Observations have, therefore, been made upon quite a large number of varieties, and in locations ranging from Victoria to Dallas, Tex., upon various types of soil, and in connection with various experiments with fertilizers and different conditions of cultivation. From a comparison of the results thus obtained it was hoped that some factors might be found which could be used practically in increasing proliferation, and thus rendering it more effective as a factor in controlling the weevil. In many cases the results of the work have been quite different from those anticipated, but enough has been learned to justify the assertion that at present proliferation is a more important factor in retarding the multiplication of the weevil than are the parasites which have thus far been found.

Large numbers of squares and bolls have been carefully examined in obtaining these records. In the examination of bolls, the lock has been made the unit rather than the boll. As a general rule, a larva confines its injury almost, if not entirely, to the lock within which the egg was originally placed. Quite frequently two or more larvæ occur within a lock, but even in such cases the injury does not often extend through the septum or partition which separates the locks.

In making a comparison of varieties considerable care is required in subdividing the classes of observations in order to render the influential conditions sufficiently uniform to make the observations fairly comparable and wherever possible to reduce the fundamental causes or stimuli producing variations in the proliferation to one essential factor. While the phenomenon in bolls is of a similar nature to that in squares, conditions in these two cases are so different that the results are not strictly comparable, and therefore separate tables have been made for squares and bolls. The effects of feeding and egg punctures also call for separate classification. This treatment of the subject necessarily multiplies the number of tables, but we hope that it will render the results more easily intelligible. The personal equation of the observer has been equalized by combining the records made by a number of investigators.

PROLIFERATION FROM FEEDING PUNCTURES IN SQUARES.

As the square precedes the boll in the natural process of development and the feeding puncture precedes oviposition in the attack of the weevil, we shall consider first the observations regarding proliferation resulting from feeding punctures made in squares. These observations include nearly 25 varieties of cotton. They are grouped by years and localities in order to bring as closely together as is possible those records which may be considered as most strictly comparable. The totals and averages for so many seasons and localities should constitute a very fair average statement of the true condition.

TABLE I.—*Proliferation resulting from feeding punctures in squares—comparison of varieties.*

Date.	Locality.	Variety.	Total number of punctured squares examined.	Squares with proliferation.		Squares with no proliferation.	
				Number.	Per cent of total.	Number.	Per cent of total.
1902. Sept. 17	Victoria, Tex	Several varieties	16	4	25.0	12	75.0
1903. July 8 to Oct. 28	....do	King	470	286	60.1	184	39.9
Aug. 10 to Oct. 19	....do	Parker	83	49	59.0	34	41.0
Oct. 25	.....do	Mascot	102	38	37.3	64	62.7
Do	.....do	Dickson	101	67	66.3	34	33.7
Oct. 24	.....do	Mit Afifi	79	59	74.3	20	25.7
Oct. 22	.....do	Ashmouni	74	35	47.3	39	52.7
Do	.....do	Jannovitch	82	62	75.6	20	24.4
Aug. 8 to Oct. 28	....do	Native	78	42	53.8	36	46.2
1905. Nov. 9	Dallas, Tex	Egyptian	53	8	15.1	45	84.9
Do	.....do	Pachon	10	3	30.0	7	70.0
Do	.....do	Kekchi	21	6	29.6	15	71.4
Sept. 24	San Antonio, Tex	Shine	70	15	21.4	55	78.6
Do	Calvert, Tex	King	33	14	42.4	19	57.6
Do	.....do	Shine	47	23	48.9	24	51.1
Do	.....do	Rowden	45	28	62.2	17	37.8
Do	.....do	Nicholson	69	32	46.4	37	53.6
Do	.....do	Triumph	25	11	44.0	14	56.0
Do	.....do	Tools	39	22	56.4	17	43.6
Do	.....do	Hawkins	36	18	50.0	18	50.0
Do	.....do	Russell	18	7	38.9	11	61.1
Do	.....do	Allen	30	15	50.0	15	50.0
Do	.....do	Bohemian	27	15	55.6	12	44.4
Do	.....do	Truitt	34	15	44.1	19	55.9
Do	.....do	Hetty	31	4	12.9	27	87.1
Do	.....do	Native	34	16	47.0	18	53.0
Do	.....do	Territory	163	71	43.6	92	56.4
Totals and averages			1,870	965	[a] 51.6	905	[a] 48.4

[a] Weighted average.

The general average for all the various seasons and localities shows that in squares approximately one-half of all feeding punctures stimulate proliferation. The highest percentage shown is 75.6 per cent in "Jannovitch" (an Egyptian variety), at Victoria, Tex., on October 22, 1903, while the lowest percentage found was 12.9

per cent for "Hetty," at Calvert, Tex., September 24, 1905. These figures show a wide range. Five series of observations show proliferation in less than 30 per cent of the squares fed upon; three series show between 30 and 40 per cent; eight series between 40 and 50 per cent; six show between 50 and 60 per cent; three between 60 and 70 per cent. It appears, therefore, that the range, while wide, is well balanced, the large majority of observations showing between 40 and 60 per cent.

PROLIFERATION FROM FEEDING PUNCTURES IN BOLLS.

Turning now to an examination of proliferation following feeding punctures made in bolls, records are presented of the observations made during 1905 only. These observations include 18 varieties and 3 localities.

TABLE II.—*Proliferation resulting from feeding punctures in bolls.*

Date of examination.	Variety.	Locality.	Total bolls examined.	Total locks in lot.	Locks with feeding punctures only. With proliferation. Number.	Locks with feeding punctures only. With proliferation. Per cent of total.	Locks with feeding punctures only. Without proliferation. Number.	Locks with feeding punctures only. Without proliferation. Per cent of total.	Per cent of punctured locks in which proliferation followed.
1905.									
Sept. 25	King	Calvert, Tex.	80	340	123	36.2	32	9.4	79.4
Do	Shine	do	91	398	159	40.0	22	5.5	87.9
Do	Rowden	do	63	274	94	34.3	56	20.5	62.7
Do	Nicholson	do	83	374	195	52.2	39	10.4	83.3
Do	Triumph	do	57	247	146	59.1	69	27.5	68.0
Do	Tools	do	109	462	239	51.7	56	12.1	81.0
Do	Hawkins	do	110	462	302	65.4	124	26.8	70.9
Do	Russell	do	98	419	254	67.8	29	6.9	89.7
Do	Allen	do	83	371	180	48.5	37	10.0	83.0
Do	Bohemian	do	90	399	173	43.4	8	2.0	95.6
Do	Truitt	do	94	419	187	44.6	21	5.0	90.0
Do	Hetty	do	97	419	248	59.2	20	4.8	92.5
Do	Native	do	94	407	122	30.0	22	5.5	84.7
Do	Territory	do	655	2,830	1,251	44.0	284	10.0	81.5
Sept. 27	Shine	San Antonio, Tex.	156	656	164	25.0	65	10.0	71.6
Nov. 11	Mit Afifi	Dallas, Tex.	79	244	64	26.2	14	5.7	82.0
Do	Pachon	do	2	7	5	71.4	0	0.0	100.0
Do	Korean	do	1	3	2	66.7	0	0.0	100.0
Totals and averages			2,042	8,731	3,908	[a] 44.8	898	[a] 10.3	[a] 81.3

[a] Weighted average.

The bolls examined all showed distinct external signs of weevil injury. Among them, however, fully one-fourth of the total number of locks were found to have no noticeable internal injury, and probably a majority of these locks would have matured had the bolls been allowed to remain upon the plants. As the bolls examined were selected especially for weevil injury, it appears that their condition would probably be worse than the average in fields where the weevil has done its worst damage. The figures are of interest, therefore, as indicating that even under the most severe conditions of weevil injury sufficient seed would still be produced to replant the field. While practically one-half of the squares attacked showed proliferation, a far greater proportion of the locks attacked by the weevil showed a similar formation.

From these records it appears that 55 per cent of the nearly 9,000 locks examined received feeding punctures only. Among the locks thus injured, an average of slightly over 81 per cent showed distinct evidence of proliferation. A comparison with Table I indicates that in bolls proliferation occurs from feeding punctures in a higher percentage of cases than it does in squares. The records upon Pachon and Korean cottons were included in the table because of the special interest attached to these varieties, but the data regarding them are too meager to be reliable in drawing definite conclusions regarding proliferation in them, and they should be excepted in making a comparison of varieties. It is to be regretted that the two varieties mentioned produced so little fruit at Dallas, Tex., that more extensive data regarding them could not be obtained, and the fruiting occurred so late in the season that no bolls could mature. The range in the percentage of cases in which proliferation results from feeding punctures in bolls is not so great as it appears to have been in squares. This fact may possibly be due to more uniform climatic and cultural conditions, as nearly all the records for bolls were made from material collected in one locality at the same time.

These records appear to the writer to show a remarkable uniformity, and to indicate that among the 15 varieties mentioned in the table which are most clearly comparable there is little difference in the natural tendency to proliferate in response to feeding injuries made by the weevil in bolls.

INFLUENCE OF DIFFERENT LOCALITIES AND SEASONS.

OBSERVATIONS ON SQUARES.

This series of observations was made to determine, if possible, what influence different localities and seasons might have upon proliferation in the same variety of cotton. While similar data have been secured for a number of varieties, the exhibit following is restricted to the two varieties on which the largest number of observations was made, as the conclusions which may be drawn therefrom are consequently most reliable. In the case of King cotton, different seasons as well as localities are represented, while with Shine, different localities are represented at approximately the same time. In compiling this table, both feeding and egg punctures have been included. It has seemed desirable also to present the figures showing the effect which the proliferation has had upon the weevil stages found.

TABLE III.—*Proliferation in King and Shine squares—different seasons and localities.*

Variety and locality.	Date.	Number of squares examined.	Squares with proliferation.					Squares without proliferation.					Per cent of all dead stages found with proliferation.	Increase in rate of mortality due to proliferation.
			Number.	Per cent of total.	Weevil stages alive.	Weevil stages dead.	Per cent of stages found dead.	Number.	Per cent of total.	Weevil stages alive.	Weevil stages dead.	Per cent of stages found dead.		
KING.														
Victoria, Tex.	1904. July to October.	822	437	53.1	87	14	13.8	385	46.9	165	0	0.0	100.0	13.8
Calvert, Tex.	1905. August and September.	218	124	56.2	64	24	27.3	94	43.8	61	2	3.2	92.3	24.1
Totals and averages		1,040	561	[a]54.0	151	38	[a]20.0	479	[a]46.0	226	2	[a].9	[a]95.0	[a]19.1
SHINE.	1905.													
Calvert, Tex.	August	229	122	53.3	59	28	32.2	107	46.7	52	5	8.8	84.8	23.4
San Antonio, Tex.	September	443	212	47.9	152	51	25.1	231	52.1	178	18	9.7	73.9	15.4
Totals and averages		672	334	[a]49.7	211	79	[a]27.2	338	[a]50.3	230	23	[a]9.1	[a]77.5	[a]18.1
General totals and averages		1,712	895	[a]52.3	362	117	[a]24.4	817	[a]47.7	456	25	[a]5.2	[a]82.4	[a]19.2

[a] Weighted average.

Two rather striking contrasts are shown by a study of the figures in this table. First, in the 1,040 King squares examined there were found 417 weevil stages, while in 672 Shine squares examined there were found 543 stages. Stated in a way to make the contrast most evident, in King there was found an average of one weevil stage for each 2.5 squares; in Shine an average of one weevil stage for each 1.24 squares. That is, in Shine there were almost exactly twice as many weevil stages found, in proportion to the number of squares examined, as in King. This is a factor, however, which would naturally vary widely with the degree of infestation found in the field and it is a well-established fact that weevils were much more numerous and injurious at San Antonio in 1905 than they were at Calvert, Tex. The second striking contrast is to be found in the percentage of mortality. In King squares without proliferation only 0.9 per cent of the weevil stages found were dead, while in Shine squares without proliferation ten times as large a proportion, or 9.1 per cent, of the stages found were dead. Doubtless much of this difference may have been due to seasonal rather than to varietal differences, since it appears that in King squares at Calvert in 1905 the percentage of mortality was much greater than at Victoria in 1904.

In other respects there is a most striking uniformity in the results shown. The percentage of squares showing proliferation varies only between 49.7 per cent for Shine and 54 per cent for King. The average increase in mortality apparently due to the proliferation varies only between 18.1 per cent for Shine and 19.1 per cent for King. It appears that the "normal mortality," due to other causes than proliferation, varies much more widely in different localities and seasons than does the increase in mortality attributable to the presence of proliferation.

OBSERVATIONS ON BOLLS.

Before drawing any general conclusion from Table III the similar records of examinations of bolls should be considered. The same varieties and localities are used as in Table III, the only change being the inclusion of the examination of King bolls made at Victoria, Tex., in 1903.

Table IV.—*Comparison of proliferation in King and Shine bolls in different seasons and localities.*

Variety and locality.	Date.	Total bolls examined.	Total locks examined.	Locks with proliferation.				
				Number.	Per cent of total.	Weevil stages alive.	Weevil stages dead.	Per cent of stages found dead.
KING.								
Victoria, Tex.	1903. Oct. 14	620	2,666	1,398	52.4	53	50	48.5
Victoria, Tex.	1904. Sept. 5	200	865	417	48.2	13	2	13.3
Do	Oct. 1	198	843	468	55.5	14	4	22.2
Calvert, Tex.	1905. Sept. 25	80	340	176	51.7	30	8	21.0
SHINE.								
Calvert, Tex.	Sept. 25	91	398	234	58.8	37	21	36.2
San Antonio, Tex.	Sept. 27	156	656	422	64.3	189	69	26.7
Totals and averages		1,345	5,768	3,115	[a] 54.0	336	154	[a] 31.4

Variety and locality.	Date.	Locks without proliferation.					Percent of all dead stages in locks with proliferation.	Locks with feeding punctures only.		
		Number.	Per cent of total.	Weevil stages alive.	Weevil stages dead.	Per cent of stages found dead.		With proliferation.	Without proliferation.	Percent with proliferation.
KING.										
Victoria, Tex.	1903. Oct. 14	1,268	47.6	34	11	24.4	82.0	....	....	....
Do	1904. Sept. 5	448	51.8	0	0	0.0	100.0	14	5	73.7
Do	Oct. 1	375	44.5	8	1	11.1	80.0	56	27	67.5
Calvert, Tex.	1905. Sept. 25	164	48.3	7	1	12.5	53.3	123	32	79.4
SHINE.										
Calvert, Tex.	Sept. 25	164	41.2	7	0	0.0	75.0	159	22	88.0
San Antonio, Tex.	Sept. 27	234	35.7	8	1	11.1	98.6	164	65	71.6
Totals and averages		2,653	[a] 46.0	64	14	[a] 18.0	[a] 91.7	516	151	[a] 77.4

[a] Weighted average.

In the case of bolls the conclusions indicated are quite similar to those which have been stated for squares. The percentage of locks showing proliferation in consequence of weevil injury is remarkably uniform, varying through a range of only 16 per cent in three years in three localities and with two varieties. Furthermore, the percentage is almost identical with that shown for squares.

By far the highest percentage of mortality among weevils in bolls was that found in Victoria in 1903, when an average of 40.5 per cent of all immature stages was found dead in King bolls. The weather during a six-weeks period preceding the examination was exceptionally cool and dry, but a heavy rain falling shortly before the examination was made may have been a factor in markedly increasing the mortality. The percentage of dead stages in locks in the presence of proliferation for all the bolls examined averaged 7 per cent higher than it did in squares. The percentage of dead stages in locks where no proliferation occurred was also higher in bolls than in squares by nearly 15 per cent, so that the increase in mortality apparently due to proliferation was only about 13.4 per cent in bolls, whereas it was 19.2 per cent in squares. It would appear that in bolls the normal mortality, which has no relation to proliferation, is not as clearly influenced by varying climatic conditions as it appears to be in the squares.

EFFECTS OF CLIMATIC CONDITIONS.

In connection with Tables III and IV, some statement should be made regarding the climatic conditions prevailing in each locality during the periods in which the observations recorded were being made. The statements following are based largely upon the published Weather Bureau records. We shall begin with the records for Victoria in 1903, considering first the data for about six weeks preceding the examination of bolls made on October 14, 1903, as we may safely assume that a large majority of these bolls had been attacked within that time. While preceding conditions, especially those regarding rainfall, may have had some influence upon plant growth during this period, we believe they may safely be disregarded, assuming that the conditions immediately prevailing would be most significant in their influence upon the growth of the plant, the development of the weevil stages in buds and bolls, and the formation of proliferation.

The mean average temperature at Victoria during September, 1903, was 77.2° F., which was 3.7° below the normal. During the first thirteen days of October the mean temperature averaged 75.8°, which was about normal. Precipitation during September was very slight, amounting to only 0.54 inch, which was nearly 3 inches below the normal. During the first thirteen days of October the rainfall amounted to 1.75 inches, which was 0.42 inch above the normal.

At Victoria in 1904, from July 1 to October 10, the mean temperature averaged 80.6° F., which was 1.17° below the normal. During the same period the total rainfall amounted to 8.50 inches, which was only 0.57 inch below the normal. In a general way this season might be described as slightly cooler than usual, with the humidity and rainfall practically normal.

No records are available for Calvert, Tex., but the reports from Hearne, which is only 8 miles from Calvert, will serve to indicate the temperature and rainfall of the latter place with sufficient accuracy. During the months of July and August, 1905, the mean temperature averaged 82.85° F., which was 2.8° above the normal. No rain fell during September, and during August the rain amounted to only 0.63 of an inch. For these two months, therefore, the rainfall was 4.33 inches below the normal. The season may be characterized in general as exceptionally hot and dry. At San Antonio the mean temperature during these two months averaged 82.5° F., which was 1.6° above the normal. During this period the rainfall amounted to 2.31 inches, which was 3.35 inches below the normal. Here again the season was exceptionally hot and dry.

Considering these climatic conditions in relation to the figures given in Table III, the following conclusions would seem to be indicated: (1) The percentage of squares which proliferate from attack by the weevil is not greatly affected by varying conditions of temperature and moisture; (2) the increase in mortality due to proliferation is not greatly affected by the varying climatic conditions as shown for these localities; (3) the normal mortality of the weevil which may not be attributed to proliferation is decidedly greater during especially hot dry weather than it is under cooler and more moist conditions.

As for bolls, the range in formation of proliferation in locks from 48.2 to 64.3 per cent is not unexpectedly great. The most remarkable fact is that the maximum percentage for locks and the minimum percentage for squares occur at the same time, in the same locality, and with the same variety. It is plain, therefore, that climatic conditions can not be held responsible for these contradictory results. The records concerning percentages of mortality are also too inconsistent to point to any constant effect of the climatic conditions upon this particular point. The records for "normal mortality" also fail to show any consistent increase or decrease which may be attributed to exceptional conditions of heat or drought. The reason why the records for bolls fail to show as consistent conclusions as are indicated for squares may probably be found in the comparative difference in the length of the growing season for each and in the essential difference in the nature of the two sets of organs. Obviously the square would be subject to climatic changes occurring within only a short period of time as compared with the boll, which would therefore exhibit a more composite result of any influential conditions affecting it.

It is probably true that the increased mortality in squares occurring during hot dry weather is more directly attributable to the absolute maximum temperature experienced than it is to the slightly higher mean average temperature prevailing. The observations which have been here recorded refer only to conditions found in squares which have been attacked by the weevil, but before they have fallen to the ground. After squares have fallen the influence of hot dry weather in largely raising the percentage of mortality wherever the squares become directly exposed to the sun is unquestionably a still more important factor in destroying the immature stages of the weevil.

EFFECT ON PROLIFERATION OF FERTILIZING THE SOIL.

In accordance with indications shown by some of the examinations of bolls made in 1903, it was expected that fertilization of cotton might produce a considerable increase in the percentage of cases in which proliferation followed injury by the weevil. A test of this point required a comparison of a considerable number of varieties under similar cultural and soil conditions with check plats unfertilized for each variety. Tests of this nature were instituted at the beginning of the season of 1904. Favorable conditions for such observations were also furnished by the field experiment at Calvert, Tex., during the season of 1905. Fourteen varieties were there grown upon Brazos bottom lands. Each fertilized plat received an application of 400 pounds of acid phosphate per acre. Conditions in all plats were similar with the exception of fertilization.

TABLE V.—*Comparison of proliferation on fertilized and unfertilized plats of 14 varieties of cotton on uniform soil and receiving otherwise similar treatment.*

Variety.	Part of plant.	Plat on which grown.	Total number of squares examined.	Total number of locks examined.	Squares or locks with proliferation.					Squares or locks without proliferation.					Per cent of total dead stages found with proliferation.	Apparent increase in rate of mortality as a result of proliferation.
					Number.	Per cent of total.	Weevil stages alive.	Weevil stages dead.	Per cent of stages dead.	Number.	Per cent of total.	Weevil stages alive.	Weevil stages dead.	Per cent of stages dead.		
King	Squares	Fertilized	119		67	56.3	39	16	27.3	52	43.7	36	1	2.7	88.2	24.6
		Unfertilized	99		57	57.6	25	8	24.2	42	42.4	25	1	3.8	88.9	20.4
	Bolls	Fertilized		167	98	58.7	10	2	16.7	69	41.3	1	1	50.0	66.7	− (33.3)
		Unfertilized		173	98	45.1	20	6	23.1	95	54.9	6	0	14.3	85.9	8.8
Shine	Squares	Fertilized	122		70	57.4	30	17	36.2	52	42.6	27	4	12.9	81.0	23.3
		Unfertilized	107		52	48.6	26	11	29.7	55	51.4	25	1	3.8	91.7	25.9
	Bolls	Fertilized		200	85	42.5	4	20	83.3	115	57.5	6	0	0.0	100.0	83.3
		Unfertilized		198	149	75.3	33	1	3.0	49	24.7	1	0	0.0	100.0	3.0
Rowden	Squares	Fertilized	99		55	55.6	45	3	6.3	44	44.4	35	1	2.8	75.0	3.5
		Unfertilized	108		50	46.3	38	27	41.5	58	53.7	40	1	2.4	96.5	39.1
	Bolls	Fertilized		134	83	62.0	10	4	28.6	51	38.0	0	0	0.0	100.0	28.6
		Unfertilized		140	87	62.1	5	23	82.1	53	37.9	5	3	37.5	88.5	44.6
Nicholson	Squares	Fertilized	104		47	45.2	38	4	9.5	57	54.8	45	6	11.8	40.0	− (2.3)
		Unfertilized	101		65	64.4	48	8	14.3	36	35.6	27	0	0.0	100.0	14.3
	Bolls	Fertilized		155	99	63.9	38	13	25.5	56	30.1	1	0	0.0	100.0	25.5
		Unfertilized		219	173	79.0	14	2	12.5	46	21.0	0	0	0.0	100.0	12.5
Triumph	Squares	Fertilized	96		54	56.2	24	9	27.3	42	43.8	28	2	6.7	81.8	
		Unfertilized	98		61	62.2	22	5	18.5	37	37.8	21	2	8.7	71.4	
	Bolls	Fertilized		90	61	65.6	5	0	0.0	29	34.4	0	0	0.0		
		Unfertilized		157	96	61.2	13	0	0.0	61	38.8	0	0	0.0		
Tools	Squares	Fertilized	109		54	49.5	33	9	21.4	55	50.5	26	6	18.8	60.0	2.6
		Unfertilized	113		51	45.1	31	4	11.4	62	54.9	30	2	6.2	66.7	5.2
	Bolls	Fertilized		252	166	65.8	8	2	20.0	86	34.2	1	0	0.0	100.0	20.0
		Unfertilized		210	159	75.7	17	1	5.6	51	24.3	1	0	0.0	100.0	5.6
Hawkins	Squares	Fertilized	108		59	54.6	40	10	20.0	49	45.4	30	2	6.2	83.3	13.8
		Unfertilized	106		55	51.9	31	14	31.1	50	48.1	32	4	11.1	77.8	20.0
	Bolls	Fertilized		253	177	70.0	11	2	15.4	76	30.0	1	0	0.0	100.0	15.4
		Unfertilized		209	146	70.0	8	0	0.0	63	30.0	1	0	0.0		
Russell	Squares	Fertilized	118		59	50.0	40	13	24.5	59	50.0	40	3	7.0	81.2	17.5
		Unfertilized	128		57	44.5	37	8	19.9	71	55.5	51	3	5.6	72.7	14.3
	Bolls	Fertilized		211	170	80.6	14	2	12.5	41	19.4	1	0	0.0	100.0	12.5
		Unfertilized		208	138	66.3	21	4	16.0	70	33.7	5	0	0.0	100.0	16.0
Allen	Squares	Fertilized	120		72	60.0	47	19	30.2	48	40.0	42	2	4.5	90.5	25.7
		Unfertilized	121		71	58.7	50	20	28.6	50	41.3	39	0	0.0	100.0	28.6
	Bolls	Fertilized		192	147	76.5	12	2	14.3	45	23.5	1	1	50.0	33.3	(35.7)
		Unfertilized		179	116	64.8	27	0	0.0	63	35.2	7	0	0.0		

Bohemian	Squares	Fertilized	114		63	55.3	32	14	34.3	51	44.7	33	2	5.7	87.5	28.4
		Unfertilized	133		66	42.1	55	9	14.1	67	57.9	40	7	14.9	56.2	(0.8)
	Bolls	Fertilized		194	147	75.8	42	3	6.7	47	24.2	1	0	0.0	100.0	6.7
		Unfertilized		205	153	74.6	22	1	4.3	52	25.4	4	0	0.0	100.0	4.3
Truitt	Squares	Fertilized	116		56	48.3	42	16	27.6	60	51.7	33	1	3.0	94.1	24.6
		Unfertilized	105		55	52.4	34	9	20.9	50	47.6	40	0	0.0	100.0	20.9
	Bolls	Fertilized		195	120	61.5	47	2	4.0	75	38.5	7	0	0.0	100.0	4.0
		Unfertilized		224	162	72.3	27	2	7.0	62	27.7	2	0	0.0	100.0	7.0
Hetty	Squares	Fertilized	140		69	49.3	36	28	43.7	71	50.7	35	20	36.4	58.4	7.3
		Unfertilized	116		33	28.5	25	9	26.5	83	71.5	56	13	18.8	40.9	7.7
	Bolls	Fertilized		208	164	78.8	40	1	2.4	44	21.2	2	0	0.0	100.0	2.4
		Unfertilized		211	174	82.5	17	6	26.1	37	17.5	0	0	0.0	100.0	26.1
Native	Squares	Fertilized	116		62	53.4	40	12	23.1	54	46.6	33	2	5.7	85.7	17.4
		Unfertilized	118		56	47.5	34	15	30.6	62	52.5	40	0	0.0	100.0	30.6
	Bolls	Fertilized		200	93	46.5	29	4	12.1	107	53.5	0	0	0.0	100.0	12.1
		Unfertilized		207	120	58.0	36	3	7.7	87	42.0	4	0	0.0	100.0	7.7
Territory	Squares	Fertilized	123		75	61.0	58	12	17.0	48	39.0	25	1	3.8	92.3	13.2
		Unfertilized	118		63	53.4	52	11	17.5	55	46.6	28	1	3.4	91.7	14.1
	Bolls	Fertilized		243	175	72.0	22	8	26.7	68	28.0	0	0	0.0	100.0	26.7
		Unfertilized		194	143	73.7	19	3	13.6	51	26.3	2	0	0.0	100.0	13.5
Totals and averages for squares			3,175		1,654	[a] 52.1	1,052	350	[a] 25.0	1,520	[a] 47.9	962	88	[a] 8.4	[a] 80.0	[a] 16.6
Totals and averages for bolls				5,428	3,679	[a] 67.8	571	117	[a] 17.0	1,749	[a] 32.2	60	5	[a] 7.7	[a] 95.1	[a] 9.3

[a] Weighted average.

At the end of Table V are given totals and average percentages for squares and for bolls, but the differentiation of the results for fertilized and unfertilized plats is more clearly shown in Table VI, which is practically a summary of Table V. In each case the totals show the amount of data upon which the conclusions rest.

TABLE VI.—*Summary of data appearing in Table V, showing effect of fertilization upon formation of proliferation, and the mortality of weevils in squares and bolls.*

Part of plant.	Plat on which grown.	Number of squares and locks examined.	Per cent of total squares and locks showing proliferation.	Weevil stages alive.		Weevil stages dead.		Per cent of total stages dead.		Average increase in mortality with proliferation.	Average percentage of mortality.
				With proliferation.	Without proliferation.	With proliferation.	Without proliferation.	With proliferation.	Without proliferation.		
Squares	Fertilized	1,604	50.5	544	466	182	53	25.0	10.2	14.8	18.9
Do	Unfertilized	1,571	49.5	508	494	159	35	23.8	6.6	17.2	16.2
Bolls	Fertilized	2,694	66.2	302	22	65	2	17.7	8.3	9.4	17.1
Do	Unfertilized	2,734	69.5	286	38	52	3	15.4	7.3	8.1	14.5
Totals and averages		8,603	[a]61.9	1,640	1,010	458	93	[a]21.4	[a]8.4	......	......

[a] Weighted average.

An examination of Table VI shows that proliferation follows weevil attack in approximately two-thirds of the cases in bolls and in approximately one-half of the cases in squares. As between squares on fertilized and unfertilized plats, there is found a difference of only 1 per cent, which is in favor of the fertilized plats. In the figures for bolls there is shown a difference of 3.3 per cent in favor of the unfertilized plats. Even if both these differences were on the same side of the account, they are too small to justify the conclusion that fertilization with acid phosphate, as used in these experiments, appreciably affected the percentage of instances in which proliferation followed weevil attack.

From a comparison of the mortality percentages it appears that, although among the squares from fertilized plats there is a slightly larger percentage of squares showing proliferation following weevil attack, there is, on the contrary, a smaller difference in the average mortality which may be attributed to the presence of proliferation than is found among the squares from unfertilized plats. With squares on the unfertilized plats having a slightly smaller percentage showing proliferation there is a somewhat higher average mortality apparently due to the presence of proliferation. In a similar comparison with bolls, among those grown on fertilized ground showing proliferation in 66.2 per cent of the injured locks, there was an average increase of 9.4 in the percentage of mortality, while in bolls grown on unfertilized ground showing proliferation in 69.5 per cent of injured locks the average excess of mortality apparently due to proliferation is only 8.1 per cent.

The second significant feature of Table VI is that showing the effect of fertilization upon the mortality of the weevil without regard to the presence or absence of proliferation. A comparison of the percentages of mortality shown in the last column of the table shows us that in the case of squares there is a difference of 2.7 per cent and in the case of bolls of 2.6 per cent in favor of the fertilized plats. These differences are so nearly alike in both squares and bolls as to indicate that fertilization, as practiced in this case, would increase the general average mortality by a small percentage, but that this increase was not due to any increase in the proportion of cases showing proliferation.

One general fact should be stated in regard to field conditions in connection with these observations. As has been stated, the experiment was located in the Brazos bottom. The application of fertilizer produced little apparent difference in the size of plants, and the difference between varieties was by no means as marked as is usually the case. It is possible that upon soil naturally less fertile greater differences might have been produced both as regarding varietal characters and the effect of the application of fertilizer. From the data at hand, however, we would not venture to predict that such differences would result in any greater increase in the mortality of the weevil than has been found in the observations here reported.

PROLIFERATION FOLLOWING OVIPOSITION IN SQUARES.

The next series of observations to be presented will deal with a comparison of varieties in regard to the formation of proliferation following egg punctures in squares. The comparison includes observations made during three seasons and includes about 25 varieties. The table shows also the increase in mortality due, apparently, to proliferation. It is impossible to obtain a close comparison of varieties in this examination, as the conditions of soil, cultivation, and season were so diverse, and the influence of these varying conditions can not as yet be even closely estimated. In the following tabulation are included records where there were less than 100 observations in the series. It is noticeable that the greatest differences in the percentage of squares examined which showed proliferation occurs in cases where examination was made of only a small number of squares and late in the season. It is evident that the data in these cases are insufficient as a basis for reliable conclusions regarding those particular varieties, but the figures may be included in the totals of examinations made without materially disturbing the general averages.

TABLE VII.—*Comparison of varieties for proliferation from egg punctures in squares.*

Date.	Locality.	Variety of cotton.	Total number of squares examined.	Squares with proliferation.				Squares without proliferation.				Average per cent mortality.	Per cent of total dead stages in squares with proliferation.	Per cent of mortality apparently due to proliferation.
				Number found.	Per cent of total examined.	Number weevil stages found.	Per cent of weevil stages dead.	Number found.	Per cent of total examined.	Number weevil stages found.	Per cent of weevil stages dead.			
1902. Sept. 17	Calvert and Victoria, Tex.	Several varieties	105	44	41.9	59	30.5	61	58.1	113	19.5	23.3	45.0	11.0
1904. July 25 Aug. 28	Victoria, Tex	King	1,307	688	52.6	162	11.0	619	47.4	268	0.0	4.6	100.0	11.0
July 28 Sept. 19	do	Parker	377	200	53.1	56	9.0	177	46.9	82	2.4	5.0	71.4	6.6
July 28 Aug. 8	do	Sunflower	174	59	33.9	18	0.0	115	66.1	89	0.0	0.0	0.0	0.0
July 28 Sept. 25	do	Dickson	171	101	59.1	19	0.0	70	40.9	21	0.0	0.0	0.0	0.0
July 28 Sept. 25	do	Mascot	169	70	41.4	13	7.7	99	58.6	22	4.5	5.7	50.0	3.2
July 8 Sept. 24	do	Mit Afifi	159	89	56.0	37	19.0	70	44.0	50	0.0	8.0	100.0	8.0
July 8 Sept. 22	do	Ashmouni	123	50	40.7	18	16.7	73	59.3	34	0.0	5.8	100.0	5.8
July 8 Sept. 22	do	Jannovitch	141	82	62.4	22	9.0	59	37.6	39	0.0	3.3	100.0	3.3
July 8 Sept. 28	do	Native	333	141	42.3	71	5.6	192	57.7	102	1.0	2.9	80.0	4.6
1905. Aug. 24	Calvert, Tex	King	105	57	54.3	31	12.9	48	45.7	32	6.3	9.5	66.7	6.6
Do	do	Shine	105	55	52.9	40	25.0	50	47.1	23	17.4	22.2	71.4	7.6
Aug. 25	do	Triumph	87	43	49.4	24	50.0	44	50.6	22	9.1	30.4	85.7	40.9
Do	do	Tools	114	40	35.1	30	16.7	74	64.9	38	21.1	19.1	46.2	4.4
Aug. 28	do	Hawkins	106	49	46.2	47	31.9	57	53.8	43	11.6	22.2	75.0	20.3
Do	do	Russell	126	43	34.1	42	23.8	83	65.9	61	8.2	14.6	66.7	15.6
Do	do	Allen	117	59	50.4	59	42.4	58	49.6	50	4.0	24.8	92.5	38.4
Do	do	Bohemian	128	53	41.4	48	22.8	75	58.6	52	17.3	20.0	55.0	5.5
Do	do	Truitt	102	41	40.2	38	36.8	61	59.8	42	4.8	18.7	93.3	32.0
Do	do	Hetty	131	52	40.0	52	34.6	79	60.0	53	11.3	22.9	75.0	23.3
Aug. 29	do	Native	120	56	46.7	53	28.3	64	53.3	36	5.5	19.1	88.2	22.8
Do	do	Territory	815	334	41.0	314	26.7	481	59.0	250	5.6	17.4	85.7	21.1
Sept. 11	do	King	113	67	59.3	57	35.1	46	40.7	31	0.0	22.7	100.0	35.1
Do	do	Shine	124	67	54.0	45	40.0	57	46.0	34	3.0	24.1	94.7	37.0
Do	do	Rowden	207	105	50.7	113	26.5	102	49.3	77	2.6	16.8	93.7	23.9

Do	do	Nicholson	205	112	54.6	98	12.2	93	45.4	78	7.7	10.2	66.7	4.5
Do	do	Triumph	107	72	67.3	83	29.0	35	32.7	36	5.5	21.8	92.3	23.5
Do	do	Tools	108	65	60.2	47	17.0	43	39.8	26	0.0	11.0	100.0	17.0
Do	do	Hawkins	108	66	61.1	48	18.7	42	38.9	25	4.0	13.7	90.0	14.7
Do	do	Russell	122	73	60.0	66	16.7	49	40.0	36	2.8	11.8	91.7	13.9
Do	do	Allen	124	84	67.7	77	18.2	40	32.3	33	0.0	14.5	100.0	18.2
Do	do	Bohemian	119	76	63.9	62	19.4	43	36.1	30	0.0	13.0	100.0	19.4
Do	do	Truitt	119	70	58.8	63	17.5	49	41.2	33	0.0	11.4	100.0	17.5
Do	do	Hetty	125	50	40.0	46	41.3	75	60.0	48	8.3	24.5	82.6	33.0
Do	do	Native	114	62	54.4	48	25.0	52	45.6	39	0.0	13.8	100.0	25.0
Do	do	Territory	753	494	65.6	449	19.6	259	34.4	172	1.0	13.7	98.8	18.6
Sept. 27	San Antonio, Tex.	Shine	443	212	47.9	203	24.6	231	52.1	196	9.2	17.5	74.0	15.4
Nov. 9	Dallas, Tex.	Egyptian	65	18	27.7	10	40.0	47	62.3	27	4.0	13.5	80.0	36.0
Nov. 11	do	Pachon	25	5	20.0	2	0.0	20	80.0	13	0.0	0.0	0.0	0.0
Do	do	Kekchi	50	16	32.0	10	40.0	34	68.0	19	5.3	17.2	80.0	34.7
Do	do	Korean	4	1	25.0	1	0.0	3	75.0	3	0.0	0.0	0.0	0.0
Totals and averages			8,150	4,121	[a] 50.6	2,801	[a] 22.3	4,029	[a] 49.4	2,488	[a] 5.0	[a] 14.2	[a] 83.5	[a] 17.3

[a] Weighted average.

Studying Table VII with a view to making a comparison of the varieties in regard to their tendency to proliferate in response to egg punctures and larval injuries, it appears that, in cases where one hundred or more observations were made, the highest percentage showing proliferation was 67.7 per cent, found in Allen at Calvert, Tex., on September 11, 1905. A previous examination of this variety shows, however, only 50.4 per cent, which is almost exactly the average percentage found for all varieties. The average of all observations on Allen shows 59.3 per cent having proliferation. The lowest percentage, from observations which are closely comparable, was 33.9 per cent, found in Sunflower at Victoria, Tex., in 1904. Unfortunately there are no other observations upon Sunflower by which this result may be checked to see whether it may be considered as a somewhat constant tendency in that variety. This being true, it would not be safe to conclude that Sunflower shows the least tendency to proliferate among the varieties examined. It should be noted that the average of the three Egyptian varieties grown at Victoria in 1904 is 52.3 per cent, which is slightly above the general average for all varieties examined. Considering all examinations for each of the four varieties having more than 500 observations each, we find for King 53.2 per cent, for Territory 52.8 per cent, for Shine 49.7 per cent, and for Native 45.7 per cent. Because of the larger number of observations made the average percentages shown for these four varieties are undoubtedly the most reliable of all those given in the table. It appears to the writer from the small variation of 7.5 per cent that the tendency of different varieties to proliferate in response to weevil injury by oviposition or by larval feeding is a remarkably uniform character. Much more extensive examinations would be required to determine the positive status of so many varieties in respect to this tendency to proliferate.

SUMMARY OF RECORDS FOR FOUR VARIETIES.

Examining more closely the portion of Table VII relating to mortality, we find that the percentage of mortality in squares with proliferation ranges from 0 to 50 per cent. The latter figure is found in Triumph at Calvert, August 25, 1905. A general average for the 4,121 squares examined is 22.3 per cent. For the four varieties—Territory, King, Shine, and Native—a closer comparison can be made by presenting the figures in tabular form.

TABLE VIII.—*Comparison of four varieties, each having over 500 observations in Table VII, showing average percentages of mortality and influence of proliferation thereon.*

Variety.	Number of squares examined.	Squares with proliferation.			Squares without proliferation.				Average increase in rate of mortality due to proliferation.
		Number of squares with proliferation.	Number of weevil stages found.	Per cent of stages found dead.	Number of squares without proliferation.	Number weevil stages found.	Per cent of stages found dead.	Average number of stages per 100 squares.	
Territory	1,568	828	763	22.4	740	422	3.7	76	18.7
King	1,525	812	250	16.7	713	331	.6	38	16.1
Shine	672	334	288	27.1	338	253	9.1	81	18.0
Native	567	259	172	17.5	308	177	1.7	62	15.8

In squares having proliferation the range in mortality varies between 16.7 per cent for King and 27.1 per cent for Shine. In squares without proliferation this range is between 0.6 per cent for King and 9.1 per cent for Shine. The most striking point in this comparison is shown in the last column of the table giving the average increase in mortality due to proliferation in each variety. In spite of the variations of 8.5 and 10.4 in the preceding percentage columns there is shown in the last column a variation of only 2.9 per cent. The unfavorable influence of proliferation appears, therefore, to be very nearly constant in different varieties, instead of varying widely, as early indications had led us to anticipate that it might do.

In respect to the rapidity of maturity these four varieties may be fairly considered as ranging from the very earliest to the late varieties. Rapid maturing or, in other words, "short season" cotton does not seem to increase especially either the formation of proliferation or the percentage of mortality occurring in the squares.

INCREASE OF MORTALITY ACCOMPANYING MORE SEVERE ATTACK.

While only injured squares were selected for these examinations there was a difference in the severity of the weevil attack in different fields. It was evident during the growing season that the field in which most of the data for Shine was obtained was being more severely injured than any other in which observations were made. The figures show some very interesting results of this condition, if, indeed, they do not indicate the explanation for the increased severity of the attack. The four varieties may be arranged in the order of the increasing proportion of weevil stages to number of squares examined. The figures for the number of weevil stages found and for the stages dead in squares without proliferation are reduced to the common basis of 1,000 squares for convenience in comparing.

Increased mortality in squares without proliferation accompanying increased severity in weevil attack.

Variety.	Number of squares.	Number of weevil stages found.	Number of stages dead.	Per cent of mortality.
King	1,000	380	6	1.6
Native	1,000	620	17	2.7
Territory	1,000	760	37	4.9
Shine	1,000	810	91	11.2

The comparison given above shows very clearly the great increase in mortality accompanying increased severity in the weevil attack. The data here given furnish a very interesting confirmation of the conclusions stated in Bulletin No. 51 of the Bureau of Entomology (p. 119). The statement most directly confirmed is here repeated.

> By this time the number of weevils has become so great that the supply of squares is insufficient to meet their need for both feeding and oviposition. Selection of squares so that these two portions of their attack may be kept separate can no longer be exercised. Female weevils are forced to deposit their eggs in squares which have either received other eggs or been largely fed upon, and a much larger proportion of squares at this time shows that feeding punctures are made in squares having eggs or larvæ. By these two factors the mortality among young larvæ especially is greatly increased.

An examination of the figures given shows that in Territory cotton were found twice as many weevil stages as in King, and among these there were 6 times as many dead. In Shine cotton having more than twice as many weevil stages as the King, 15 times as many stages were dead.

INCREASED MORTALITY IN SQUARES AND BOLLS DUE TO PROLIFERATION.

Next in order will be a special study of the increased mortality in squares and bolls which may be attributed directly to the formation of proliferation. The figures for squares and bolls together include more than 20,000 observations. In many cases the records are taken from data which have been used in preceding tables.

TABLE IX.—*Summary of observations showing increased mortality in squares and bolls caused by proliferation.*

Year of observations.	Number of localities covered.	Number of varieties included.	Squares examined.			Per cent of mortality in squares.		Increase in mortality due to proliferation.	Number of bolls examined.	Locks examined.			Per cent of mortality in locks.		Increase in mortality due to proliferation.
			Total number.	Number with proliferation.	Per cent with proliferation.	With proliferation.	Without proliferation.			Total number.	Number with proliferation.	Per cent with proliferation.	With proliferation.	Without proliferation.	
1902	4	4	105	44	41.9	30.5	19.5	11.0	......	......	......	......	......	......	......
1903	1	1	......	......	......	......	......	......	246	1,033	434	42.0	15.0	5.0	10.0
1903	1	1	......	......	......	......	......	......	452	1,898	995	52.4	28.4	12.8	15.6
1904	1	9	2,954	1,480	50.0	9.6	.6	9.0	......	......	......	......	......	......	......
1904	2	2	......	......	......	......	......	......	398	1,708	885	51.8	18.2	11.1	7.1
1905	1	14	4,504	2,365	52.5	19.6	5.5	14.1	......	......	......	......	......	......	......
1905	1	6	771	372	48.2	28.6	.3	28.3	......	......	......	......	......	......	......
1905	1	1	443	212	47.9	25.1	9.7	15.4	......	......	......	......	......	......	......
1905	1	4	144	40	27.8	34.8	3.2	31.6	......	......	......	......	......	......	......
1905	1	14	......	......	......	......	......	......	1,802	7,821	5,069	64.8	16.7	8.5	8.2
1905	1	1	......	......	......	......	......	......	82	254	158	62.2	14.6	0.0	14.6
Totals and averages			8,921	4,513	[a]50.6	[a]17.2	[a]3.7	[a]13.5	2,980	12,714	7,541	[a]59.3	[a]15.5	[a]9.2	[a]6.3

[a] Weighted average.

SUMMARY OF RESULTS OF OBSERVATIONS.

FORMATION OF PROLIFERATION.

In the portion of Table IX relating to squares it should be noticed especially that proliferation follows weevil punctures in approximately one-half of the squares attacked, either for feeding or for oviposition. The constancy of this proportion may be most clearly shown by bringing together the general averages relating to this point found in preceding tables.

Average percentage of squares in which proliferation follows weevil punctures as shown in several preceding tables.

	Per cent.
Table I. Feeding punctures in squares—proliferation formed	51.6
Table III. Comparison King and Shine squares—proliferation formed	52.3
Table V. Squares from fertilized and unfertilized plats—proliferation formed	52.1
Table VI. Squares from fertilized plats—proliferation formed	50.5
Table VI. Squares from unfertilized plats—proliferation formed	49.5
Table VII. Egg punctures in squares—proliferation formed	50.5
Table IX. Increased mortality from proliferation—proliferation formed	50.6

The general average of all these results shows that proliferation follows weevil attack in 51 per cent of all cases.

In the portion of the table relating to bolls it appears that proliferation follows weevil attack in a somewhat higher proportion of cases than it does in squares. A list of the figures for bolls is here given similar to that shown for squares.

Average percentage of locks in which proliferation follows weevil punctures in bolls as shown in several preceding tables.

Table II. Feeding punctures in bolls. Proliferation formed in 44.8 per cent of total locks and in 81.3 per cent of locks actually fed upon.

Table IV. King and Shine bolls. Proliferation formed in 54 per cent of total locks and in 77.4 per cent of locks actually fed upon.

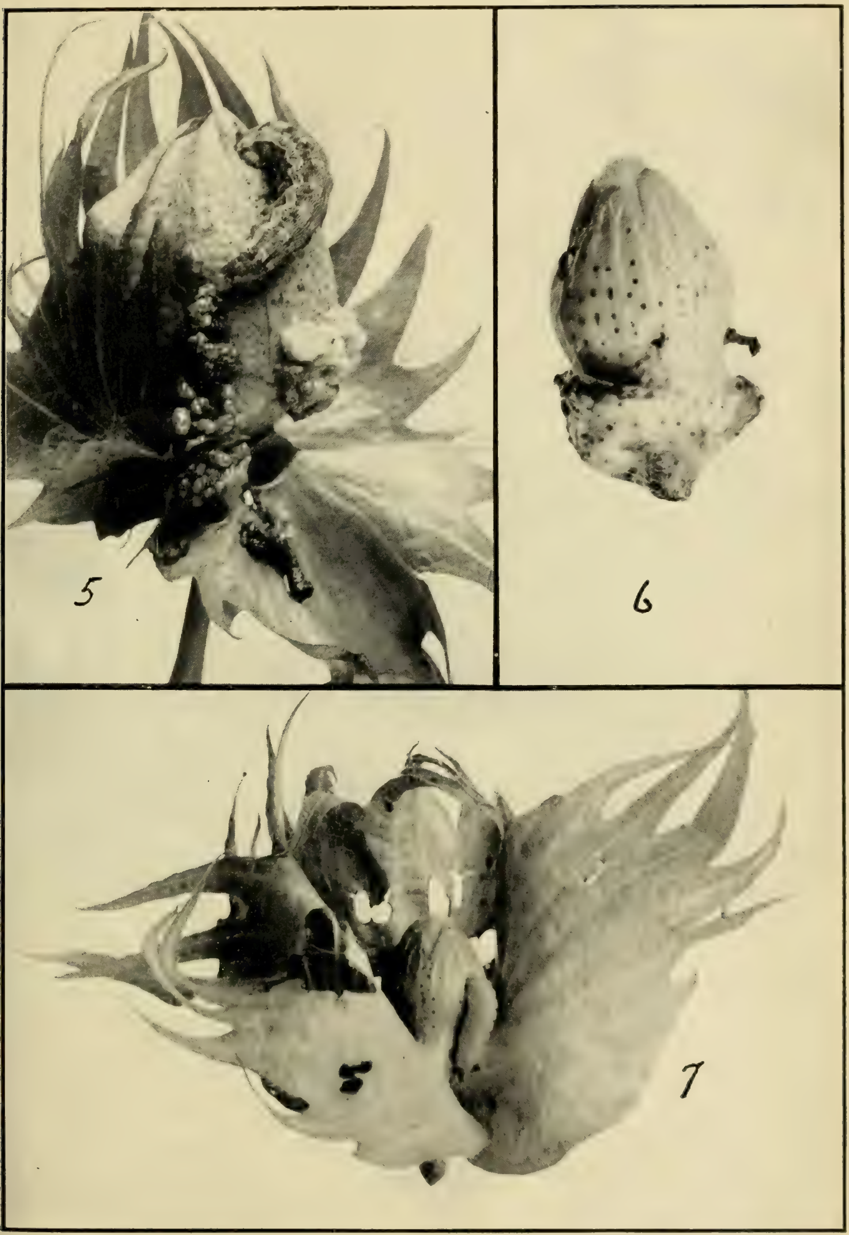
Table V. Fertilized and unfertilized bolls. Proliferation formed in 67.8 per cent of total locks.

These figures indicate that proliferation is stimulated by weevil punctures in somewhat more than 55 per cent of all locks in bolls attacked. The figures in regard to feeding punctures only, show that proliferation results in nearly 80 per cent of the locks thus attacked. It should be noted here that in many cases the proliferation may have been stimulated by secondary causes, such as the entrance of fungi or by decay starting in the open feeding punctures.

INCREASED MORTALITY OF WEEVIL STAGES DUE TO PROLIFERATION.

As would naturally be expected, a study of the increase of mortality attributable to proliferation will show a somewhat greater variation in the figures for various series of observations than has been found in the percentages of instances in which proliferation occurs. Thus for squares there is found a range of from 9 to 31.6 per cent, the general average being only about 13.5 per cent. For bolls the range is not as great as for squares, being only from 7.1 per cent to 15.6 per cent, while the general average increase in mortality in bolls was found to be only about 6.3 per cent. This increase is scarcely one-half as great as was the increase found in squares.

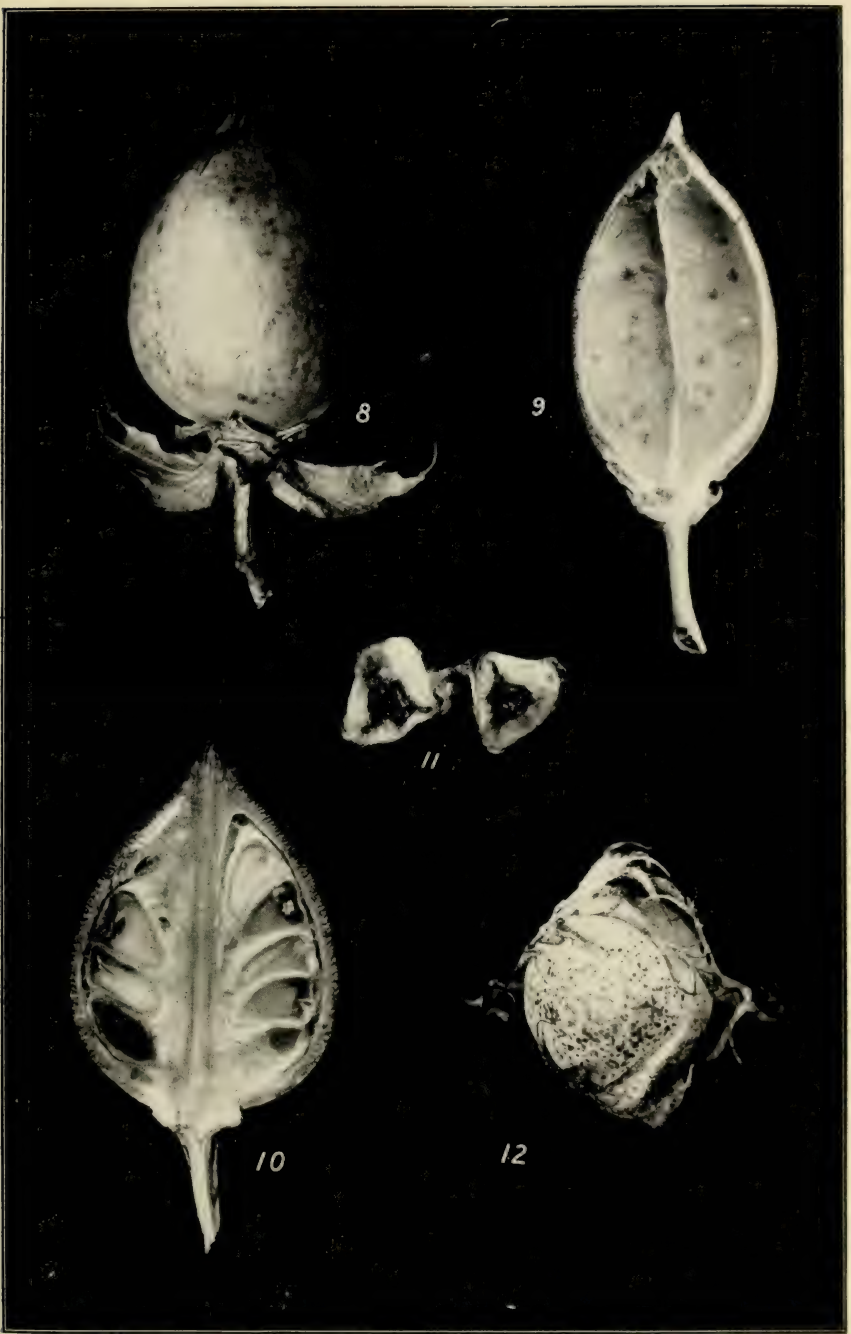
In neither squares nor bolls is the percentage of mortality sufficiently high to appreciably delay the time of maximum infestation by the weevil, since, if hibernated weevils survived in their usual numbers, the number of weevils developing would be abundantly able to totally infest a field by the time the weevils of the third generation had deposited a majority of their eggs. However, the fact that proliferation does evidently increase the mortality in both squares and bolls must be regarded as a very encouraging sign. It indicates clearly one of the most promising lines of investigation in the future development of cotton varieties which, by possessing this quality in a still greater degree and in combination with other desirable characters, may prove most desirable for culture in the weevil-infested area. So far as our present knowledge is concerned, we may say that the mortality of the weevil is more greatly increased by only two other natural factors known—(1) by the effect of long-continued dry weather when the sun has direct access to the fallen squares upon the ground, and (2) by the work of a widely distributed species of native ant, *Solenopsis geminata* Fab.



OTHER INSECTS THAN BOLL WEEVIL CAUSING PROLIFERATION.

Fig. 5.—Bollworm inciting proliferation in boll (after Quaintance), slightly enlarged. Fig. 6.—Feeding punctures of young bollworm in square, proliferation protruding on right side, enlarged two diameters. Fig. 7.—Square borer inciting proliferation, slightly enlarged. Figs. 6 and 7 original.

PLATE III.



PROLIFERATION FROM INTERNAL AND EXTERNAL STIMULATION.

Fig. 8.—Exterior view of apparently uninjured boll. Fig. 9.—View showing proliferation starting on inner side of carpel shown in fig. 8, due to punctures of bugs. Fig. 10.—Proliferation in seeds due to punctures of *Pentatoma ligata*. Fig. 11.—Section of seed proliferating from Pentatoma puncture. Fig. 12.—Boll attacked by anthracnose, which incited proliferation. Figs. 8–11 slightly enlarged; fig. 12 natural size. (Original.)

STIMULATION TO PROLIFERATION BY CAUSES OTHER THAN WEEVIL ATTACK.

PROLIFERATION STIMULATED BY OTHER INSECTS.

Since beginning this study of proliferation it has been noticed frequently that it occurs commonly in localities where the weevil is not found and from many other inciting causes. Some of the most abundant proliferations have been found in bolls and squares following the attack of young bollworms (*Heliothis obsoleta* Fab.). (See Pl. II, figs. 5, 6.) In many cases small columns of purely proliferous material have been found projected from the punctures made by the pressure produced within the square or boll. Similar cases resulting from the attacks of young square-borers—*Uranotes melinus* Hbn. (Pl. II, fig. 7) or other Thecla larvæ—are to be found in a probably larger proportion of the cases of attack than is generally true with weevils. Many species of bugs commonly produce proliferation of internal tissues in bolls, though no mark of their puncture can be seen in an external examination of the boll (Pl. III, figs. 8, 9). In this way a Mexican bug (*Pentatoma ligata* Say) does great damage by inciting proliferation in the seeds (Pl. III, figs. 10, 11) and preventing the opening of the boll. In a series of examinations covering 4,000 punctures made by this bug 34 per cent of the punctures were found to show distinct proliferation. A number of species of native bugs have been found to incite proliferation in a similar manner. *Leptoglossus phyllopus* L. and *Nezara hilaris* Say have been studied especially, and proliferation has been found in a large percentage of punctures made by these species. In the fields the injury of several species is likely to be so similar in nature and effect as to make it impossible to separate the work of the various species concerned. Thus *Euschistus servus* Say, *Nezara hilaris* Say, and *Thyanta custator* Fab. commonly occur together. In an examination of bolls attacked by these three species proliferation was found in 52 per cent of the total number of locks examined. Other species of Leptoglossus, especially *L. oppositus* Say and *L. zonatus* Dall., have frequently been taken upon cotton, and undoubtedly they incite proliferation exactly as *L. phyllopus* is known to do. *Largus succinctus* L. also feeds upon cotton bolls and in all probability incites proliferation, although specific instances have not been observed.

PROLIFERATION STIMULATED BY ATTACKS OF FUNGI.

In examining large series of bolls it was found that a small percentage showed distinct and characteristic proliferation on the inner side of carpels, which were severely attacked externally by a fungous disease of cotton known as anthracnose. No other cause for the proliferation could be seen, and the number of observations leaves little doubt that the anthracnose (Pl. III, fig. 12) was the cause of the proliferation. In an examination of 1,800 bolls 71 locks showed proliferation from anthracnose. Undoubtedly various species of fungi find favorable places for attack in the cavities formed by open feeding punctures, and these also appeared to incite proliferation in many cases, though it is possible that their attack accompanied rather than caused the proliferation. In still other cases decay seemed to be the inciting agent, but whether by chemical stimulus or in some other way is not known.

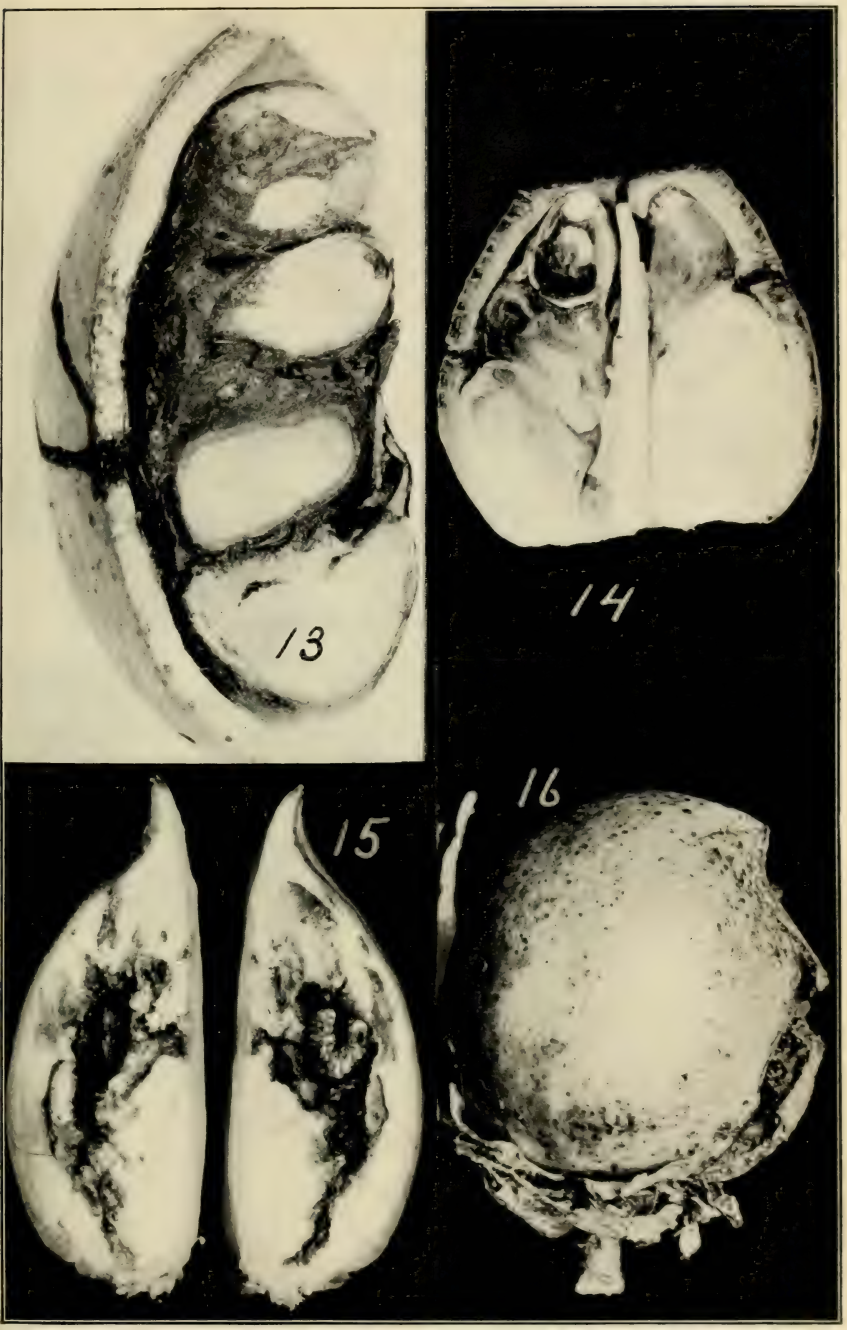
ARTIFICIAL STIMULATION TO PROLIFERATION.

In order to determine positively whether the formation of proliferation was connected specifically with weevil attack, a series of experiments was undertaken to see if it could be produced by artificial stimulation without the intervention of any insect. The experiments, as originally planned, were much more extensive than is shown by the figures which follow, but unfortunately a considerable portion of the records was destroyed in the field through the vandalism of some unknown person. The records secured are sufficient, however, to indicate reliable conclusions to be drawn from the work.

METHOD OF TREATMENT.

Punctures of two sizes were made in these tests, the smaller by a No. 12 needle, which is the smallest size that is commonly used. This needle is not as thick as the proboscis of a weevil, and it made a small puncture. The hypodermic syringe needle used would make a larger puncture than that ordinarily made by the weevil for ovipositing, but not as large as is often made in feeding. The needles were sterilized in a flame before starting a series of experiments, but not between the punctures made in the series.

The "sealing" referred to in Table X, column 1, was accomplished by using a solution of shellac in alcohol. This was not supposed to resemble in nature the mucous secretion used by the weevil in sealing her egg punctures, but was simply expected to close the punctures approximately as tightly as does the weevil. However, the shellac solution accomplished this object only partially, as in many cases it soon peeled away from the surface of the bud or boll. Only a single puncture was made in each square treated, but in more than one-third of these squares a weevil puncture was present also. The effects of a few chemical solutions when injected into buds or bolls were tested also in these experiments (Pl. IV, figs. 13, 14).



PROLIFERATION FROM ARTIFICIAL STIMULATION.

Fig. 13.—Proliferation in seeds following artificial stimulation with injection of water, enlarged three diameters. Fig. 14.—Proliferation in carpel and seed following artificial treatment with acetic acid. Fig. 15.—Proliferation from carpel and septum enveloping larva in boll. Fig. 16.—Lock of boll burst open by pressure of proliferation formed within. Figs. 14-16 slightly enlarged. (Original.)

RESULTS WITH SQUARES.

As in previous tables the records for squares and bolls are kept separate.

TABLE X.—*Results of experiments at Hidalgo, Tex., in producing proliferation in squares by artificial stimulation.*

Treatment of squares.	Number of squares treated.	Total punctures made artificially.	Total weevil punctures present.	Days from treatment to collection.	Weevil stages found.		Effects of artificial punctures.		Per cent artificial punctures showing proliferation.
					With proliferation.	Without proliferation.	Proliferation present.	Proliferation absent.	
Puncture made with No. 12 sterilized needle; unsealed	5	5	1	12.8	1	0	5	0	100.0
Puncture made with No. 12 sterilized needle; sealed with shellac	5	5	1	13.4	1	0	0	5	0.0
Puncture made with hypodermic syringe needle, sterilized; unsealed	4	4	2	14.0	2	0	0	4	0.0
Puncture made with hypodermic syringe needle, sterilized; sealed with shellac	7	7	2	12.7	2	0	2	5	28.6
Puncture made with hypodermic syringe needle; one-half drop of 2 per cent solution of formic acid injected; unsealed	3	3	0	14.0	0	0	0	3	0.0
Puncture made with hypodermic syringe needle; one-half drop of 2 per cent solution of formic acid injected; sealed with shellac	10	10	5	13.4	4	0	5	5	50.0
Puncture made with hypodermic syringe needle; one-half drop of 2 per cent solution of caustic potash injected; unsealed.	4	4	2	12.5	1	0	2	2	50.0
Puncture made with hypodermic syringe needle; one-half drop of 2 per cent solution of caustic potash injected; sealed with shellac	5	5	3	10.2	3	1	3	2	60.0
Totals and averages	43	43	16	13.0	14	1	17	26	[a] 40.0

[a] Weighted average.

It must be remembered that in all cases these artificial punctures, though sealed, resemble feeding punctures of the weevil much more closely than they do egg punctures. It is impossible to imitate artificially the natural conditions following oviposition, the hatching of the egg, and the gradually increasing irritation accompanying the growth of the larva. Really the effect of a needle puncture upon the tissues penetrated is very different from the feeding punctures of the weevil. The needle simply crushes the cells, pushing them aside from its path, and leaving the cavity it makes more or less completely filled with sap and crushed cells. In the weevil puncture the work is far more neatly done than it can be in any bungling imitation. The sharply toothed mandibles at the tip of the weevil's snout cut away the tissues smoothly without crushing or injuring adjoining cells, and the material, being eaten, is entirely removed from the cavity, leaving it dry and clean with the adjoining tissues comparatively uninjured. The difference is really about as great as in a case of the accidental amputation of a limb under a railway train as compared with the work of a skilled surgeon. The healing following these two operations might also be likened to the proliferation following artificial and weevil-made punctures. As the probability would be greatly in favor of mortification following from the untreated railway accident, so would decay be more likely to follow a needle puncture in a boll than would the proper healing of the wound by proliferation. The injection of chemical solutions by the hypodermic syringe would, in all probability, hinder rather than assist proliferation.

Unfavorable as conditions for these tests seem, it appears that proliferation was formed in a perceptible degree in 40 per cent of all cases in which artificial punctures were made. The proportion in cases where punctures were left open is slightly greater than where punctures were sealed, being 43.7 per cent in the former case, and 37 per cent in the latter case. In all these cases the proliferation was entirely distinct from that caused by larvæ when such were present. In many instances the proliferation was abundant and very plainly characteristic, in other cases there was only a slight formation with more or less of decay. The fact that the experiments were undertaken at very near the close of the growing season would account for the formation of less proliferation than might have resulted from similar experiments earlier in the season.

RESULTS WITH BOLLS.

More extensive experiments were made with bolls than with squares in testing artificial stimulation to proliferation. Part of the experiments were performed at Dallas and part at Hidalgo, Tex. The same methods were used as with squares. The number of punctures per boll averaged about six. In the experiments at Hidalgo it was difficult to find bolls which were wholly free from weevil attack. The full data from the experiments are given in the following table:

TABLE XI.—*Results of experiments in artificial stimulation to proliferation in bolls.*

Locality and variety.	Treatment of bolls.	Number of bolls treated.	Total punctures made artificially.	Total weevil punctures present.	When treated.	Days from treatment to collection.	Average size of boll, diameter.	Weevil stages found. With proliferation.	Weevil stages found. Without proliferation.	Effects of artificial punctures. No proliferation.	Effects of artificial punctures. Proliferation present. In carpel.	Effects of artificial punctures. Proliferation present. In lock.	Effects of artificial punctures. Proliferation present. In septum	Per cent of artificial punctures showing proliferation.
Dallas, Tex.:					1905.		*Inch.*							
Mit Afifi	Puncture made with No. 5 sterilized needle; unsealed	3	9	0	Oct. 14	19.0	1	0	0	4	9	5	0	55.6
Red cotton	do	4	19	0	do	10.0	1	0	0	4	15	7	0	79.0
King	do	3	15	3	do	31.0	1	0	1	0	15	5	0	100.0
Mit Afifi	Puncture made with hypodermic-syringe needle; water injected; unsealed	5	24	2	do	8.6	4/5	0	0	15	1	7	0	31.8
King	do	5	40	0	do	11.2	1	0	0	32	0	8	0	20.0
Mit Afifi	Puncture made with hypodermic-syringe needle; 2 per cent solution formic acid injected; unsealed.	2	9	0	do	4.0	1/3	0	0	3	0	6	0	66.7
Red cotton	do	4	30	0	do	9.5	3/4	0	0	6	4	24	1	80.0
Four varieties	do	4	30	1	do	13.0	1	1	0	13	17	0	0	56.7
Red cotton	Puncture made with hypodermic-syringe needle; 2 per cent solution of acetic acid injected; unsealed.	2	14	1	do	17.0	1	0	0	6	8	8	1	61.4
Egyptian	do	2	12	0	do	14.0	3/4	0	0	6	6	6	0	50.0
Texas wool	do	2	16	0	do	21.0	1	0	0	15	1	0	0	6.2
King	do	4	32	0	do	9.0	1¼	0	0	16	16	0	0	50.0
Do	Puncture made with No. 12 sterilized needle, one-fourth inch deep; unsealed	10	182	4	Oct. 20	8.5	1	1	0	132	45	5	0	27.5
Do	Puncture made with sterilized hypodermic-syringe needle; unsealed	9	172	1	Oct. 21	13.7	1⅛	1	0	169	3	0	0	2.0
Egyptian	Puncture made with No. 12 sterilized needle; sealed with shellac	9	38	0	Nov. 16	9.6	2/3	0	0	21	17	0	3	47.4
Hidalgo, Tex.:														
Native seed	Puncture made with No. 12 sterilized needle; unsealed	19	120	27	Nov. 23	14.0	......	8	0	78	42	34	4	35.0
Do	Puncture made with No. 12 sterilized needle; sealed with shellac	23	60	24	do	13.4	......	14	0	30	30	20	0	50.0
Do	Puncture made with sterilized hypodermic-syringe needle; unsealed	22	113	27	do	13.0	......	12	0	66	47	41	2	41.6
Do	Puncture made with sterilized hypodermic-syringe needle; sealed with shellac	23	66	17	do	13.3	......	12	0	25	41	17	0	62.1
Do	Puncture made with sterilized hypodermic-syringe needle; one-half drop of 2 per cent formic acid solution injected; unsealed.	8	26	10	do	13.6	......	5	0	13	11	13	3	50.0
Do	Puncture made with sterilized hypodermic-syringe needle; one-half drop of 2 per cent formic acid solution injected; sealed with shellac.	10	31	19	do	13.7	......	7	0	18	8	13	1	42.0
Do	Puncture made with sterilized hypodermic-syringe needle; one-half drop of 2 per cent caustic potash solution injected; unsealed.	5	16	8	do	13.6	......	2	0	7	5	8	1	56.2
Do	Puncture made with sterilized hypodermic-syringe needle; one-half drop of 2 per cent caustic potash solution injected; sealed with shellac.	10	29	14	do	13.4	......	1	0	18	11	11	1	40.7
Totals and averages		188	1,103	158	....	13.0	0.9	64	1	697	352	238	17	a 36.8

a Weighted average.

It should be stated that the attempt to seal punctures by applying a solution of agar-agar was not successful, as upon drying it would peel away from the boll, leaving the puncture practically open. The sealing with a solution of shellac resulted successfully in most cases.

Among the 1,103 artificial punctures made proliferation resulted in 36.8 per cent. While this percentage is hardly half that found in Table II for feeding punctures of the weevil, it seems fully as large as should be expected from the unfavorable conditions prevailing in these tests. Among the 604 unsealed punctures at Dallas proliferation resulted in 30 per cent. Among the 223 instances of proliferation recorded from these unsealed punctures 62.8 per cent were from the inner side of the carpel, 36.3 per cent were in the seeds, and 1 per cent in the septa separating the locks. A comparison with the results from the 38 sealed punctures at Dallas shows in the latter case proliferation formed in 44.7 per cent of the punctures. Among the 20 instances of proliferation resulting, 85 per cent occurred in the carpel and 15 per cent in the septa.

COMPARISON OF RESULTS FROM SIMPLE NEEDLE PUNCTURES WITH EFFECTS OF CHEMICAL INJECTIONS.

Comparing next the results from simple needle punctures with those from chemical injections for the Dallas experiments, it is found that from the needle punctures proliferation resulted in 24.1 per cent of the total cases, while from the chemical injections it resulted in 45.9 per cent of cases. It should be stated, however, that decay was much more common in the cases of chemical treatment, and in many locks it was impossible to tell whether the decay had closely followed or whether it had caused the proliferation.

An examination of the records for Hidalgo shows that proliferation resulted from 44.6 per cent of all simple needle punctures and from 45.1 per cent of those receiving chemical injections.

COMPARISON OF RESULTS FROM SEALED AND UNSEALED PUNCTURES.

In a comparison of results from 164 sealed and 630 unsealed simple needle punctures it is found that proliferation resulted in 53.7 per cent of the sealed punctures and in 28.1 per cent of those unsealed. In the chemically treated punctures proliferation resulted in 47 per cent of the 249 unsealed and in only 40 per cent of the 60 sealed. As these percentages in chemically treated punctures stand in inverse proportion to those in simple needle punctures, it does not appear that a well-founded conclusion can be drawn as to the influence which the sealing of punctures may have upon the subsequent formation of proliferation.

CONCLUSIONS.

Several important and obvious conclusions may be drawn from the results of the artificial stimulation of proliferation. Proliferation in buds and bolls does not depend essentially for its stimulation upon insect injury of any particular kind. It becomes unnecessary to assume that any irritating secretion is deposited by the weevil with the egg. It has been shown conclusively that proliferation may occur entirely apart from weevil presence. Proliferation may result from a large number of causes, of which the following are noted in this bulletin: Weevil feeding punctures, weevil egg punctures, injury by the larva during its feeding period, bollworm punctures, square-borer punctures, feeding punctures of various bugs, fungous attacks in insect punctures, anthracnose, and artificial punctures of the bud or boll.

MANNER IN WHICH PROLIFERATION CAUSES DEATH OF WEEVIL STAGES.

REARING LARVÆ ON PURELY PROLIFEROUS FOOD.

In order to determine whether proliferation caused the death of larvæ by starving or poisoning them, numerous experiments have been performed. Unhatched eggs and larvæ just hatched have been placed in the midst of masses of purely proliferous formation; and these have been kept in a tight, moist chamber and transferred to fresh masses of proliferation as frequently as necessary to preserve proper conditions for the larvæ. In spite of these frequent transferences and the somewhat unnatural conditions necessary, it was found that but a very small proportion of the larvæ died. In some cases the growth was completed in masses of proliferation which were completely decayed. This condition was allowed to exist in order to test the effect of what seemed the most unfavorable food conditions it was possible to produce so far as quality was concerned. In one series of experiments 8 very young larvæ were placed in fresh proliferous masses. Of these, 1 died on the first day, but all others reached full growth and pupated normally in from nine to twelve days, having fed on nothing but proliferous material.

In another series 8 larvæ just hatched were started in locks in which dead full-grown larvæ had been found entirely enveloped by the proliferation. Surely if proliferation were poisonous, this test should prove it, since in each case a larva had been previously killed in the lock given each young larva for food.

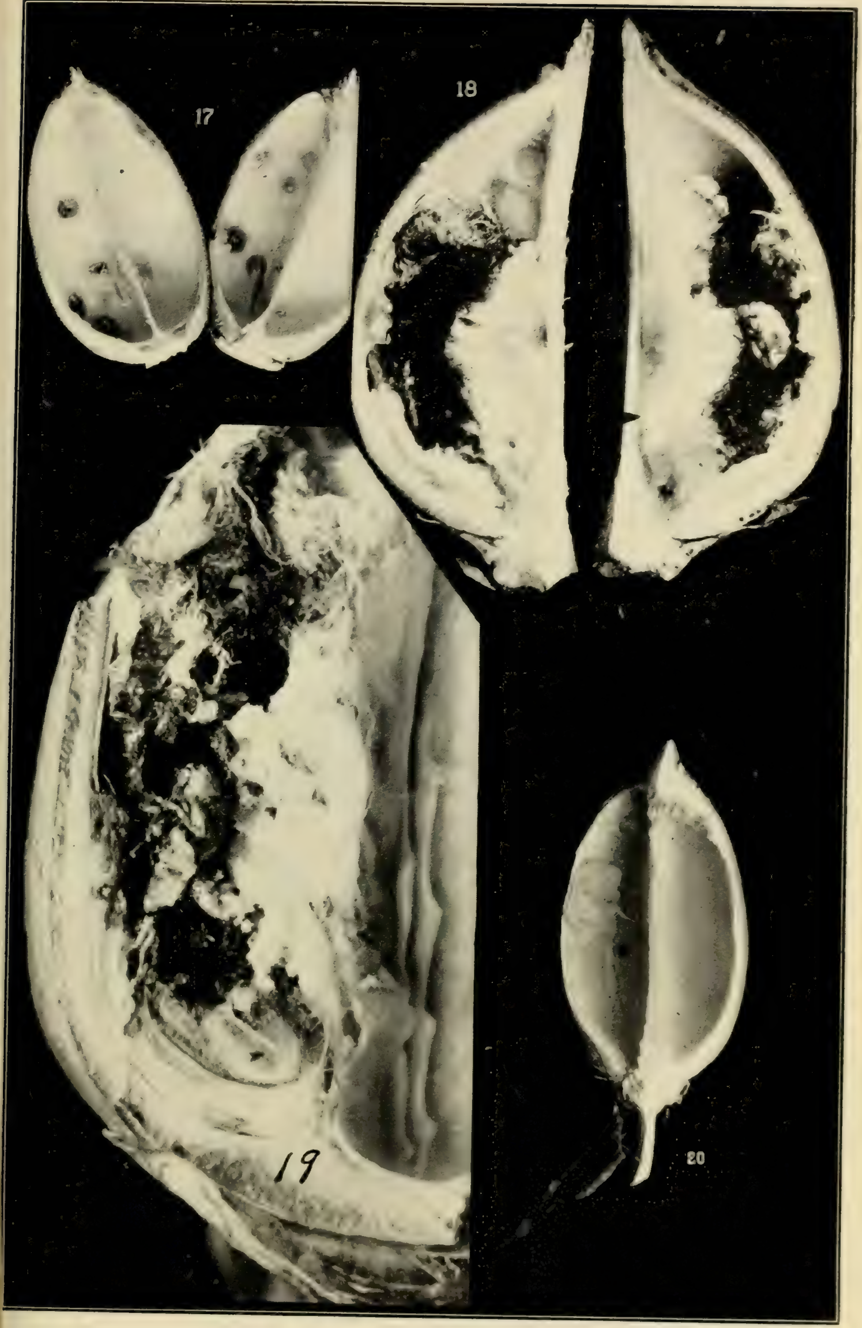
One larva was accidentally killed in examining the material on the fourth day. One larva completed its growth and pupated in the lock in which it was originally placed. Two died and the remaining 4 also pupated after being transferred to fresh locks from which dead larvæ were previously taken. Under these most unpromising conditions, therefore, 5 of the 7 larvæ tested reached the pupal stage. This experiment was performed between November 17 and December 12, 1905. The larval stage averaged about thirty days in duration. It does not follow from the length of this stage that the food conditions were even unfavorable, since at that season in bolls the length of the larval stage would undoubtedly exceed thirty days under normal field conditions. These experiments alone would be sufficient to prove that the mortality caused by proliferation is not due to insufficient nutrition or to poisonous qualities in the food material of the larvæ affected. Furthermore, the examination of thousands of squares and bolls has shown that in a very great number of cases weevils reach maturity in the field on no other food than proliferous cells.

MECHANICAL CRUSHING THE REAL METHOD.

The real cause of death in the presence of abundant proliferation will become apparent to any one who will take the pains to examine carefully a few thousand bolls which have been injured by weevil attack. In one series of observations, covering 1,800 bolls, 1,016 weevil stages were found. During this examination a partial record was kept of those cases in which the cause of death was unmistakably shown, with the following result:

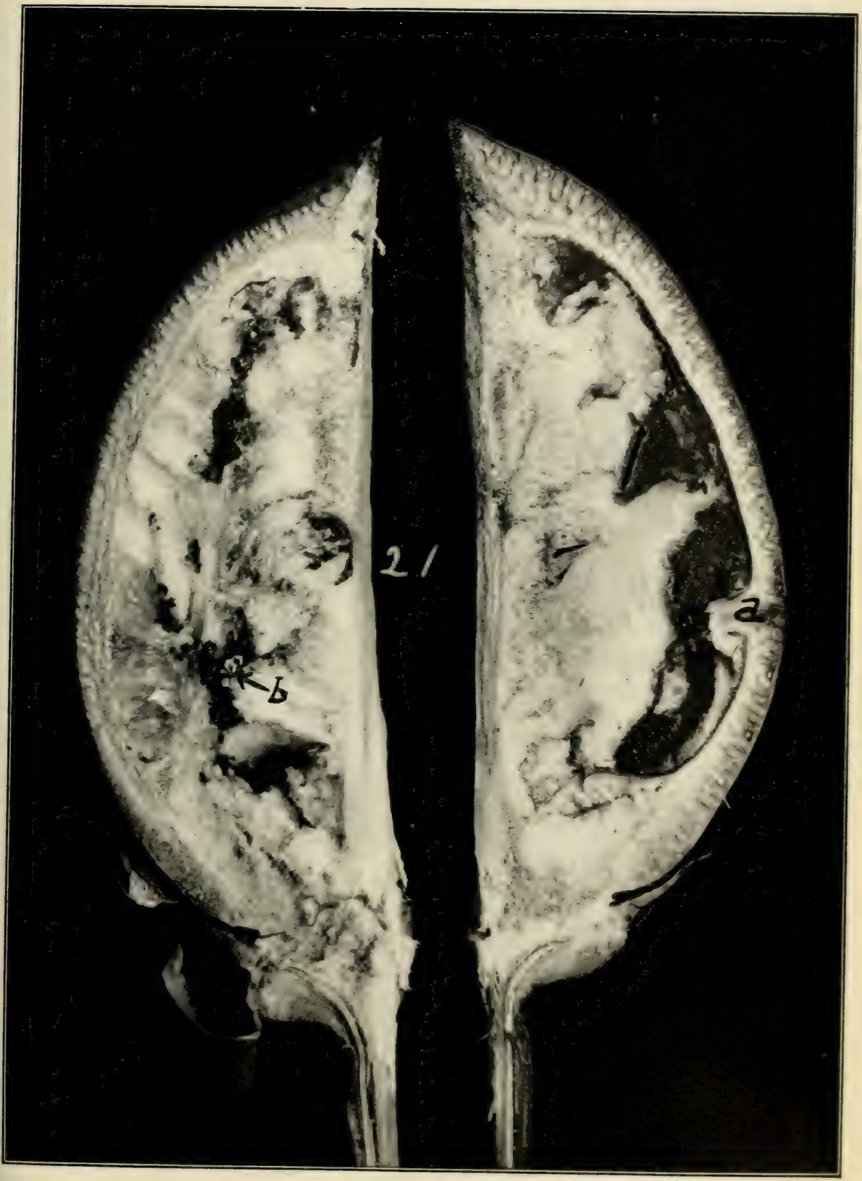
Three adults just alive, but badly deformed by pressure.
Two pupæ just alive, but badly deformed by pressure.
Two pupæ unmistakably crushed to death.
Twelve larvæ unmistakably crushed to death.

These 19 cases formed nearly 2 per cent of all the stages found. The record was not kept by all those engaged in the examination of this series of bolls and only the most unmistakable cases were recorded at all. It is certain, therefore, that this 2 per cent is but a small part of the true proportion of weevils which were killed in this way by the proliferation. Considering these facts in connection with the conclusions as to the food quality of proliferous cells, it seems safe to conclude that the great majority of deaths due to proliferation may be caused by the mechanical effect of the formation in first enveloping the larva so closely as to prevent its movement (Pl. IV, fig. 15), and then the continued formation producing sufficient internal pressure (Pl. IV, fig. 16) slowly but surely to crush to death the foe whose attack has called forth this effort at self-defense on the part of the plant. Such an explanation alone fully accords with the facts as we know them. These observations present to us in a very vivid way an illustration of the intensity of the struggle, continually going on between plant and insect life. It is a life and death struggle, and it is not always the insect that wins.



Origination and Effects of Proliferation in Bolls.

Fig. 17.—Proliferation beginning under carpel lining. Fig. 18.—Proliferation pressing into pupal cell. Fig. 19.—Adult weevil deformed by pressure of proliferation. Fig. 20.—Proliferous mass spreading over inner side of carpel. Figs. 17, 18, 20 slightly enlarged; fig. 19 enlarged four diameters. (Original.)



LOCKS COMPLETELY FILLED BY PROLIFERATION.

Fig. 21.—*a*, Point of original egg puncture and first proliferation; *b*, larva crushed by proliferation crowding upon it from all directions. Enlarged four diameters. (Original.)

EXPLANATION OF MECHANICAL ACTION.

A brief explanation of some additional points regarding the formation of proliferation may serve to show more clearly how it becomes possible for the plant to literally crush its irritating foe. The explanation will be given for bolls rather than for squares, though the real effect of proliferation is the same in squares as in bolls.

Proliferation usually begins in the layer of cells adjoining the thin, tough lining within each section of the boll. By far the greater part of this formation projects through the rupture made by the weevil in the tough lining and forms a rather hemispherical mass protruding from the inner side of the carpel (Pl. V, fig. 17) and pressing into the lock. The formation sometimes, though not always, begins before the hatching of the egg, which may be moved quite a distance, in some cases, by the pressure of the mass behind it. In other cases the egg becomes enveloped and the larva hatches into the proliferous mass. In such cases it may be destroyed early in life, though it will often make its way into the lock, eating its way as it goes. As it feeds the larva is continually injuring and irritating tissues capable of proliferation, which thus becomes started all around the larva and gradually pushes in upon it from all directions (Pl. V, fig. 18). It may happen in this way that the space which the larva has eaten out as it grew becomes filled by the masses of cells pushing in upon it and the larva can not possibly eat away the forming mass rapidly enough to preserve room for itself to move (Pl. V, fig. 20). Though it may be nearly or quite full grown, it can not escape from its narrowing prison and soon becomes so closely enveloped as to be unable to move in any direction. It is then an easy victim for the relentless pressure of forming cells and is literally crushed to death in its prison (Pl. VI, fig. 21).

Very frequently, indeed, instances are to be found in which the plant gets a tardy vengeance on the pupa or the newly transformed adult (Pl. V, fig. 19). Whether death results within a short time or the victim is allowed to emerge with only some deformity to tell of its narrow escape within the boll, depends largely upon the continuance of the proliferation. Deformed pupæ and adults are by no means uncommon and in nearly all cases they are undoubtedly the partial victims of this form of plant defense. Many of these specimens have been so deformed by pressure upon the pupa that the adult can not feed. These would be unable to make their escape from the boll did it not happen sometimes that the maturing of the boll breaks open the prison cell of these victims and turns them out only to perish slowly by starvation.

PROLIFERATION IN PLANTS OTHER THAN COTTON.

The most definite and abundant observations of proliferation in plants other than cotton have been made in two species of peppers in connection with the work of the pepper weevil (*Anthonomus æneotinctus* Champ.). Proliferation was very distinct in 93.5 per cent of the pods of sweet pepper which had been attacked by the pepper weevil. It was also found to have formed in three-fourths of the feeding punctures. In pods of the chili peppers proliferation was found in about 38 per cent of those examined and in about 34 per cent of the cases of simple feeding punctures. Among the 300 pepper pods examined no trace of mortality resulting from the proliferation was seen.

Among other plants no special observations seem to have been made to determine the presence or absence of proliferation, but it may be allowable to state here that a similar formation, which has every appearance of being homologous with proliferation in cotton, has been observed by Mr. F. C. Pratt in the pods of garden peas, by Mr. C. R. Jones in the pods of cowpeas, by Mr. A. C. Morgan in the buds of *Callirrhoe involucrata,* and by Mr. J. C. Crawford in the seed pods of mesquite. It would appear probable that when special investigation shall be made of the occurrence of proliferation in other plants than cotton it will be found a not uncommon phenomenon in very widely separated species of plants.[a] Naturally, it may not be expected to occur in response to the great majority of insect injuries, since it depends upon a number of coincident favorable conditions, and the presence or absence of some other and entirely unrelated factor may prevent or obscure its formation even where some of the essential favorable conditions are present.

CONCLUSIONS AS TO NATURE AND SIGNIFICANCE OF PROLIFERATION.

In all cases, whatever the stimulant, one factor is uniformly essential. There must be a cell injury which is not sufficiently severe to overcome immediately the vital force of the injured organ or tissue. Proliferation is simply the manifestation of a natural inherent tendency of plant cells to respond to an encountered irritation by multiplying or forming new cells. It is evidently a method of self-defense, and in the case of cotton the irritation appears to be in nearly all cases strictly mechanical. The function of proliferation in most cases is undoubtedly to repair an injury.

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[a] The possible general occurrence of proliferation as the result of insect attack is shown by the following quotation relating to *Anthonomus quadrigibbus* Say on apple, by Prof. C. S. Crandall:

> Many of the egg-cavities cut into were found to be more or less completely filled by intruding cell masses. These cell masses were quite firm in texture. Sometimes they invaded the cavity from the bottom, but often grew as wart-like excrescences from small areas on the sides of the cavities. In several instances dead larvæ were found pressed close to the cavity wall by these intruding cell masses. (Bul. 198, Ill. Exp. Sta., page 528.)

From the numerous observations dealt with in detail in the preceding pages a number of conclusions seem to be warranted. The phenomena considered are very complicated, and consequently only a few generalizations are made.

(1) In a large number of varieties of American upland cotton proliferation has been found to occur in 51 per cent of the cases of weevil attack upon squares and in 55 per cent of the cases of similar attack upon bolls.

(2) Eliminating a certain percentage of mortality, which was found in cases where no proliferation occurred, the increased rate of mortality in all weevil stages apparently caused by proliferation was, in squares 13.5 per cent and in bolls 6.3 per cent.

(3) Ordinary variations in climatic conditions seem to have comparatively little effect upon the proportion of injuries proliferating, although hot, dry weather plainly increased the mortality occurring without regard to the presence of proliferation.

(4) Contrary to a previous tentative conclusion, based upon a much smaller number of observations,[a] the upland American varieties seem to be somewhat on a parity so far as the tendency toward proliferation is concerned.

(5) The application of different fertilizers to cotton has thus far failed to show any tendency toward increasing the proliferation.

(6) Proliferous tissue is not toxic to weevils. Death results in most cases in a mechanical way from simple pressure.

(7) Proliferation is caused by the attacks of a number of different insects, and is easily produced artificially by needle punctures. Its stimulation appears to be from mechanical irritation, and, consequently, a secretion on the part of the insect does not seem to be essential.

(8) Proliferation occurs commonly in plants other than cotton as the result of insect attack or from mechanical injury. It has been noticed in the seed pods of several species of Leguminosæ and in different species of Capsicum.

PRACTICAL APPLICATION OF CONCLUSIONS FROM THIS STUDY.

The fundamental purpose underlying all this study of proliferation, its causes and its effects, is to learn, if possible, facts which may be made of practical use in the effort to grow a profitable crop of cotton in the area infested by the boll weevil, either by so controlling the multiplication of the weevil as to reduce its injury to a sufferable quantity, or by raising the crop so as to avoid the serious injury which the pest has shown itself capable of producing under the system of culture which has been customarily employed. Many factors must be considered in any hopeful solution of this most serious problem. With insect pests ounces of prevention are worth many pounds of cure. The most promising solution of the weevil problem is undoubtedly found in a combination of the factors restricting weevil development with those favoring crop improvement. The facts learned from this study of proliferation may be utilized in the class of factors restricting weevil development.

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[a] Bul. No. 51, Bureau of Entomology, U. S. Dept. of Agric., p. 134.

It appears that there is a small variation between different varieties of cotton in regard to the proportion of cases in which weevil punctures stimulate proliferation. It is evident that the presence of proliferation increases somewhat the percentage of mortality among the larvæ and pupæ in proliferating buds and bolls. The plain conclusion is that the varieties which proliferate most freely will by that characteristic tend to restrain the rapid multiplication of the weevil. It is probable that varieties may be developed by repeated selections which will be more effective than any now known in restraining weevil development in this way; still, this factor alone will probably never be of more than secondary importance in reducing the number of weevils, as other considerations will inevitably be more important in determining the most desirable variety to plant. Although the observations thus far made have failed to show any conclusive effect of fertilization of the soil upon proliferation, further investigations should be made upon this point. Much work would still be necessary to determine any constant relationship between the formation of proliferation and climatic conditions. Probably little practical use could be made of a knowledge of such climatic relationships if ascertained, as the influential factors would always remain beyond the control of the cotton planter.

The tendency to proliferate is by no means a recently acquired characteristic of cotton; therefore it should not be supposed that it is any more susceptible to such variation as will render it a still greater obstacle to weevil development than are many other characteristics which may be emphasized with equal or even greater advantage in the selection of new strains of cotton for growth in the weevil-infested area. Such selections require much time, and we may, therefore, feel somewhat encouraged to know that in the long fight yet to come we may expect this natural factor to accomplish no less than we have found it now doing toward the repression of the weevil. Of course complete reliance can never be placed in natural factors for a solution of the weevil problem. Doubtless the capacity of the weevil for adaptation to any new conditions which its food plant may present is just as great as is any adaptive capacity of the plant. Nevertheless, the interference of man is likely to throw the advantage greatly in favor of the plant. Natural factors having a controlling influence on the weevil will do their work no less effectively if the intelligent assistance of the planter be given in the planting, culture, and subsequent care of the crop. Repeated and widely varied experience has proven that the intelligent planter can, as a rule, so assist natural factors, by adopting certain changes in his methods of cultivation, as to produce a profitable crop in the face of conditions which would otherwise have insured its failure.

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